MANURES AND FERTILIZERS

THEIR NATURE, FUNCTIONS AND APPLICATION

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INTRODUCTION

This bulletin replaces "Fertilizers for Field Crops" and "Soil Fertility", two bulletins dealing with the nature and use of fertilizers and manures and which for some time past have been out of print. Much of the material in these publications has been incorporated in this bulletin but the whole has been rewritten and a considerable amount of new matter, based on the results of recent experiments with manures and fertilizers conducted by the Division of Chemistry, included.

In the preparation of this bulletin the close relationship of the use of manures and fertilizers to the maintenance and increase of soil fertility, i.e. productiveness, has been kept in mind. Further, it has been the aim to present the information in terms readily understood by the practical farmer.

This bulletin treats concisely of the following important phases of the subject: Farm Manures, their nature, care and application; Green Manures, their value and function; Commercial Fertilizers, their plant food content and economic use and Soil Amendments.

Before entering upon the discussion of the subject matter proper it will be well to briefly emphasize the importance of increasing or at least maintaining soil fertility, if farming is to be made profitable. Continuous cropping, even on soils of the finest quality, without a concomitant return of plant food and the return of humus-forming material must result in soil impoverishment and decreased crop yields.

In all branches of farming, whether it be stock-raising, dairying, grain growing, mixed farming, orcharding, or market gardening, the degree of success resulting therefrom will depend, primarily, on the crop yields obtained. While seasonal factors—rainfall and its distribution, temperature, etc.—have a determinative influence on yields, correct methods of soil management and the presence of available plant food are essential to maximum production.

Statistics and experience of the best farmers show that crop yields in Canada are, generally speaking, very much below the possible maximum. The abandonment of many farms in the older settled districts of Eastern Canada and the United States, which were originally productive, is due, not so much to their soils being of a poor type or class, as to the fact that by constant cropping and irrational methods they have become impoverished below the point of profitable culture. These farms furnish convincing evidence of the folly of

disregarding the principles of rational soil management. "Mining" the soil must inevitably lead to exhaustion of fertility and unprofitable returns. The time has arrived in many agricultural sections of the Dominion when more attention must be paid to drainage, rotation, the growth of legumes and the more liberal use of manures and fertilizers if profit-yielding returns are to be obtained. With the present high cost of labour, better and more intensive methods must be employed; 50 acres of grain yielding 40 bushels per acre is likely to be more profitable than 80 acres yielding 25 bushels. Every reasonable and economic means possible should be used to increase the available plant food in soils which are not giving satisfactory returns. Drainage, thorough tillage, and a good rotation including the growing of legumes, more manure, its care and proper application, the employment of soil amendments, and the rational use of commercial fertilizers are some of the means at the command of the farmer by which he can improve the productiveness of his fields.

CHAPTER I

PLANT FOOD AND SOIL FERTILITY

Soil fertility may be defined as the crop producing power of the soil. It depends on the plant food content of the soil, and on such factors as the physical condition of the soil, climatic and seasonal conditions—moisture and temperature—and cultural methods. The total amounts of plant food elements contained in the soil may be considered as "potential" fertility; and the rate at which this store of potential plant food may be drawn upon and made available to crops will be dependent largely on conditions of tilth and season, nitrification, etc.

Plant food may be said to exist in the soil in two forms though no sharp line of demarcation can be drawn between them. By far the larger proportion exists in a condition insoluble in the soil-moisture and is therefore not assimilable by crops. A very small proportion of the total plant food is present in a water soluble condition and it is this extremely small percentage which nourishes the crop. This may be termed "available" plant food. The conversion of the insoluble stores of plant food of the soil into forms which can be readily taken up by the plant, proceeds very slowly and it is the supply of this available plant food which controls to a great extent the fertility of the soil.

ELEMENTS OF FERTILITY

It has been found that plants, in their normal growth and development, take from the soil ten or more elements. These include nitrogen, phosphorus, potassium, calcium, sulphur, magnesium, sodium, iron, chlorine, and silicon. In addition plants require carbon, hydrogen and oxygen which they obtain from the atmosphere in the form of carbon dioxide and water.

Of the elements of plant food derived from the soil, the available supplies of but three—nitrogen, phosphoric acid (phosphorus) and potash (potassium)—tend to become deficient for crop requirements under normal conditions. These three are commonly known as the essential elements of fertility for the reason that it has been found that their available stores are more quickly depleted by cropping than the others and therefore must be returned (or furnished) if fertility is to be maintained or increased. Lime (calcium) has also been found to be deficient in many soils more especially in districts subject to heavy rainfall. In such districts an application of lime in some form may be found essential to productiveness: in fact lime may be the predominating factor for those crops which do not thrive in an acid soil.

Each one of these essential elements of fertility has a separate function to perform in the growth of the plant, and if one is deficient, crop growth will be restricted by the lack of a supply of that element although the others may be present in ample amounts for maximum production. In other words, there may be present in the soil, all the potash and phosphoric acid that the plant can utilize with but very small amounts of available nitrogen. Under these conditions good crops cannot be grown until the deficiency in nitrogen has been overcome.

PRIMARY FUNCTIONS OF THE ESSENTIAL ELEMENTS OF FERTILITY

Nitrogen promotes more particuarly the development of stem and leaf and is demanded largely during the period of active vegetation, i.e., the earlier weeks of growth. A deficiency of nitrogen results in a poor growth with a

yellowish foliage; an excess may induce too large a vegetative growth and retard seed formation and ripening. On grain crops excessive nitrogen will cause lodging.

Phosphoric Acid influences root development in the early stages and seed or fruit formation in the later stages of growth. Its importance for turnips and grain crops may thus be explained. Phosphoric acid promotes fruitfulness and, in some measure, early ripening, and is therefore important for all seed-bearing plants.

Potash is essential to the formation of carbohydrates which comprise the starches of potatoes grains, etc. the sugar of fruits and vegetables and the fibrous matter of plants.

It also aids in the production of the proteins and in the formation of well developed grain in cereals. It promotes a good growth of many crops particularly the clovers and other legumes. An ample supply of potash in the soil tends to reduce a susceptibility of crops to fungus attacks.

AMOUNTS OF PLANT FOOD IN THE SOIL

Soil analysis is a means of measuring or determining the amounts of plant food in the soil. It must, however, be pointed out that in the present state of our knowledge there is no possibility of directly and definitely correlating the chemical data with degree of fertility. Chemical analysis in itself does not furnish the evidence for the exact classification of soils as to productiveness. Soil analysis, however, has a practical usefulness in indicating marked characteristics and deficiencies, where such exist, and in suggesting appropriate fertilizers and rational methods of soil management; such data have a greater significance in the case of virgin areas than when obtained from cultivated—manured and cropped—soils. Predictions from analyses as to productiveness cannot be of a positive nature—they can only be suggestive and tentative, for the plant food content though fundamental and all-important, is only one of a large number of ever-changing factors—chemical, biological and physical—influencing and controlling plant growth.

From the statements in the preceding paragraph, it is obvious that rigid "standards of fertility" which could be used in reporting on the relative productiveness of soils, cannot be established. Nevertheless, the large number of analyses of Canadian soils made in these laboratories during the past thirty years permit us to make the following statements in respect to the significance to be attached to the essential plant food percentages.

Nitrogen.—The larger number of our good soils contain between .1 and .2 per cent, though many reach .5 per cent and some—the richest soils of the western prairies—may exceed 1.0 per cent of nitrogen. Soils containing less than .1 per cent may prove, under favourable conditions for nitrification, fairly productive, but such generally show a remunerative response to nitrogenous fertilizers. Richness in nitrogen is determined to a large degree by the organic or humus content, though the condition or stage of decomposition of this organic matter is an important factor in indicating the nitrogen's availability.

Phosphoric Acid.—The phosphoric acid in Canadian soils of average fertility usually lies between .15 and .25 per cent. Some very good loams contain from .25 to .3 per cent and a few exceed the latter figure. The adequacy or otherwise, of phosphoric acid in a soil would appear to depend largely on the accompanying amount of lime. Increased crop production has usually followed the application of phosphatic fertilizers to soils containing less than .15 per cent phosphoric acid.

In respect to the "available" phosphoric acid determined from a 1 per cent citric acid extract of the soil, it may perhaps be assumed that for cereal crops "a percentage as low as .01 seems to denote an imperative necessity for phosphatic manure, while as much as .03 would seem to indicate that there is no such immediate necessity" and "for root crops, more especially turnips, the limit would probably be higher."—(Bernard Dyer: Proceedings of the Royal Society, Vol. 35).

POTASH.—Our data indicate that good Canadian soils usually possess between .25 and .5 per cent of potash; less than .15 per cent has, in many instances, pointed to the value of potassic fertilizers.

In the case of "available" potash as obtained by the citric acid method, the conclusion of Dr. Dyer (Proceedings of the Royal Society, Vol. 68) may be tentatively adopted in that "probably when a soil in the surface depth contains as much as .01 per cent of citric-acid-soluble potash, the special application of potassic salts is not needed.

LIME.—Lime ranks next in importance to potash and phosphoric acid in a consideration of the mineral constituents of plant food. It also promotes nitrification, improves tilth and by reason of its alkalinity, is of special value in correcting sour soils. For the larger number of farm crops an application of lime in some form is necessary if the soil has an acid reaction. It may be assumed that light and sandy loams containing less than .25 per cent of lime (CaO) and clay loams less than .5 per cent will as a rule have their productiveness increased by a dressing of lime in one or other of its agricultural forms. Soils rich in organic matter, such as muck and peaty soils, very frequently respond to an application of lime, and may with advantage be raised to 1 or 1.5 per cent of that element (CaO) especially when supplied in conjunction with phosphoric acid and potash.

EFFECT OF MECHANICAL CONDITION OF SOIL ON FERTILITY

The fertility of the soil does not depend altogether on the amount and availability of the plant food present; productiveness depends in a large measure upon the physical or mechanical condition of a soil.

Soils are mixtures of clay, silt, sand, gravel, humus, etc. in varying proportions, depending to a large extent on the character of the rocks from which the soil particles were derived and the conditions under which they were laid down. They vary from heavy clay loams to light sandy loams; when the proportion of organic matter is high as compared with the mineral constituents they are known as peats or mucks. Clay loams may become impervious to water, air and heat. Many clay soils become "refractory" from lack of vegetable matter and improper cultivation, e.g. working when wet with consequent puddling of the soil particles. Loams and sandy loams may, on the other hand, be so loose and open that they leach badly and have a low moisture holding capacity. Peat and muck soils may be and generally are deficient in the mineral elements of plant food and lacking in compactness.

Thus it will be seen that if the fertility of the soil is to be eminently satisfactory, the relative proportions of the soil's components must be such that a good physical condition will result. The soil also must offer a very comfortable or convenient and suitable medium for the germination of the seed and for the growth and rapid extension of the root system. It must be well aerated and it must hold moisture. Where these conditions are fulfilled the soil is said to be in good "tilth" and the plant can best utilize the available food contained in the soil.

CAUSES OF LOSS OF FERTILITY

One of the chief causes of loss of fertility in soils is leaching of plant food, especially nitrogen. Light and sandy loams are more apt to suffer loss of nitrogen than heavier soils, due partly to their loose and open character which favours leaching and partly to their more favourable condition for bacterial activity.

The organic matter content is closely linked up with its nitrogen content; as the organic matter is dissipated (as by excessive working under certain seasonal conditions) so the nitrogen disappears. Contrariwise, methods which increase the organic matter tend to increase the soil's percentage of nitrogen.

Summer-fallowing, a cultural operation frequently necessary in order to eradicate weeds and in the semi-arid districts of Western Canada to conserve soil moisture, tends to destroy the organic matter of the soil and concomitantly dissipate its nitrogen.

The removal of plant food in crops, under irrational systems of farming in which there is continuous cropping and no attempt made to return the elements of fertility, is perhaps one of the most serious factors leading to decreased productiveness of the soil. When the greater part of the crop is fed on the farm as in dairying and stock raising, a large proportion of the elements of fertility is returned to the land in the form of manure provided the latter is properly preserved and steps taken to prevent losses of plant food through leaching, fermentation, etc.

EXHAUSTION OF SOIL FERTILITY BY CROPPING

The amounts of plant food substances contained in the more important farm crops are given in the following table:

PLANT FOOD CONSTITUENTS IN FARM CROPS

Yield per Acre (approximate average)	Nitrogen	Phosphoric Acid	Potash
	lb.	lb.	lb.
Wheat (grain) 25 bushels	30	12	7
Oats (grain) 50 bushels	34	14	10
Barley (grain) 35 bushels	30	13	9
Timothy hay, 2 tons	60	40	90
Clover hay, 2 tons	84	20	80
Corn (for ensilage) 15 tons	66	33	120
Turnips (roots) 15 tons	54	30	115
Mangels (roots) 15 tons	57	27	115
Sugar beets (roots) 15 tons	63	24	110
Carrots (roots) 12 tons	48	12	62
Potatoes (tubers) 200 bushels	42	18	60
Apple (trees in full bearing) fruit, leaves and wood	65	15	90

A 20-bushel crop of wheat (grain) removes from the soil about 24 pounds of nitrogen, 10 pounds of phosphoric acid, and 6 pounds of potash. A 200-bushel crop of potatoes (tubers) removes about 42 pounds of nitrogen, 18 pounds of phosphoric acid, and 60 pounds of potash. If we take the mean of these figures for wheat and potatoes, and assume that the average amounts represent the normal draft made by the growth of crops on the three plant food substances, we might estimate that cropping results in an annual loss to the soil of 33 pounds of nitrogen, 14 pounds of phosphoric acid, and 33 pounds of potash.

Further assuming for this argument that cropping represents the only drain on soil fertility and that no restoration of fertility takes place, how long might productiveness be maintained?

According to our estimate of the total amounts of plant food present and the rate at which these are removed by crop growth, the nitrogen would be exhausted in 113 years, the phosphoric acid 268 years, and the potash in 227 years.

While these figures must be considered as purely conjectural, they serve to emphasize the fundamental truth upon which they are based, viz: that continued cropping without a concomitant return of plant food must result in loss of soil fertility.

METHODS OF INCREASING SOIL FERTILITY

The factors which make for increased productiveness are the use of *Manures, Green Manuring, Fertilizers,* and *Soil Amendments,* and these will be discussed in detail in the following chapters. Other important factors contributing towards productiveness are drainage, cultivation, and rotations, briefly discussed as follows:—

DRAINAGE.—Many areas have good natural drainage, by reason of their topography or a more or less porous subsoil, or both. Areas not so favoured should be drained by ditches or tiles—the latter preferably, if the best results are to be obtained. Good drainage prevents water-logging, permits an earlier working and seeding of the land, and results in a warmer, moister, better aerated soil and generally brings about conditions favourable for good growth.

CULTIVATION.—The main object of cultivation—ploughing, harrowing, rolling, etc.—is to effect a good tilth which may be defined as a fine and friable condition of the soil, one which is favourable to the germinating seed and to subsequent root extension. Further, it serves to conserve moisture and promote nitrification.

Good and proper cultivation is as essential to vigorous crop growth as the application of plant food.

ROTATION.—The desirability of a rotation of crops is perhaps primarily due to its beneficial influence in keeping down weeds. It also serves towards the economic use of soil plant food since crops differ in the proportions of the essential elements which they withdraw from the soil and the depths at which they obtain them. It further assists in maintaining a favourable tilth and in soil moisture conservation.

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CHAPTER II

FARM MANURES

Farm manures constitute the most valuable by-product on the farm and should be regarded as such in their care and employment. Their application to the soil returns a large proportion of the plant food removed by crops and more especially the essential elements of fertility—nitrogen, phosphoric acid, and potash, in forms more or less readily available for plant growth. They furnish much humus-forming material and thereby improve the tilth of both light and heavy loams. Further, they inoculate the soil with bacterial life the function of which is to attack the inert potential stores of plant food in the soil, converting them into available forms for crop use.

NATURE AND COMPOSITION OF MANURE

Manures consist of the solid and liquid excreta of farm animals mixed with the litter used in bedding the stock. The solid excreta (dung) is composed of the undigested portion of the food: the liquid excreta (urine) contains products resulting from the digestion of the food; in fact, that portion of the digested food that has done its work in the animal but is not retained in the production of flesh, milk, wool, etc.

The agricultural value of any sample of manure will depend primarily upon its composition—i.e. the amounts of nitrogen, phosphoric acid, and potash and, secondarily, upon the organic matter it contains. The composition of barnyard manure will be largely determined not only by the relative proportions of solid and liquid excreta and litter making up the whole but upon such factors as the kind, age, food and function of the animal producing it, the nature of the litter employed, and the care taken in the production and preservation of the resulting manure.

The following table states in approximate terms the relative proportions of solids (dung) and liquid (urine) excreta and bedding found in fairly well-made manures of the more common farm animals. It gives the amounts of nitrogen, phosphoric acid, and potash in these components, the data expressing percentages and pounds per ton:—

APPROXIMATE AVERAGE COMPOSITION OF MANURES (FRESH) FROM VARIOUS ANIMALS

Kind of Animal	Relative Proportions of Solid Excrement, Liquid Excrement and Bedding in Manure	Pounds per ton	Nitrogen		Phosphoric acid		Potash	
			p.c.	lb.	p.c.	lb.	p.c.	lb.
Horse	Solid excreta	1,200	0·55	6·60	0·30	3·60	0·40	4·80
	Liquid excreta (urine)	300	1·35	4·05	trace		1·25	3·75
	Bedding material	500	0·50	2·50	0·15	0·75	0·60	3·00
	Total mixture	2,000	0·66	13·15	0·22	4·35	0·58	11·55
Cow	Solid excreta	1,260	0·40	5·04	0·20	2·52	0·10	1·26
	Liquid excreta (urine)	540	1·00	5·40	trace		1·35	7·29
	Bedding material	200	0·50	1·00	0·15	0·30	0·60	1·20
	Total mixture	2,000	0·57	11·44	0·14	2·82	0·49	9·75
Pig	Solid excreta	990	0·55	5·44	0·50	4·95	0·40	3·96
	Liquid excreta (urine)	660	0·60	3·96	0·10	0·66	0·45	2·97
	Bedding material	350	0·50	1·75	0·15	0·42	0·60	2·10
	Total mixture	2,000	0·56	11·15	0·30	6·03	0·45	9·03
Sheep	Solid excreta	1,206	0·75	9·04	0·50	6·03	0·45	5·43
	Liquid excreta (urine)	594	1·35	8·02	0·05	0·30	2·10	12·47
	Bedding material	200	0·50	1·00	0·15	0·30	0·60	1·20
	Total mixture	2,000	0·90	18·06	0·33	6·63	0·95	19·10
Poultry	Solid excreta	1,900	1·00	19·00	0·80	15·20	0·40	7·60
	Bedding material	100	0·50	0·50	0·15	0·15	0·60	0·60
	Total mixture	2,000	0·97	19·50	0·77	15·35	0·41	8·20

The data of the foregoing table show that there is a vast difference in composition, i.e. in percentage of nitrogen, phosphoric acid, and potash between solid and liquid excreta and, secondly, that considerable differences in plant food content exist between the manures of various animals.

The liquid portion (urine) is much richer in nitrogen and potash than the solid excreta, weight for weight. These constituents are present in the urine in a soluble and readily available form and therefore pound for pound they are worth much more than those in the solid excreta.

The nitrogen of urine (present as urea) is quickly converted into a valuable plant food, whereas the nitrogen of the undigested food in the solid excrement is but slowly changed into such compounds.

More than one-half of the nitrogen and at least three-fourths of the potash excreted by the cow—the chief manure-producing farm animal—are to be found in the urine, while most of the phosphoric acid is excreted in the feces.

VALUE OF MANURE

While it is practically impossible to assign a definite monetary value to manure, even if its plant food content has been ascertained by analysis—for the character of the soil and of the crop to which it is applied and the nature of the season will all influence its effect on the crop, it will be interesting to compute their relative values in respect to their essential elements—nitrogen, phosphoric acid and potash. For the purpose of this comparison the following values may be assigned to the plant food constituents:—Nitrogen, 20 cents per pound; phosphoric acid 7 cents and potash 5 cents per pound.

COMPARATIVE AND APPROXIMATE VALUES OF FRESH MANURES, AS CALCULATED ON THEIR PLANT FOOD CONTENT

Kind of Animal	Value per Ton
Horse	$3 45
Cow	2 90
Pig	3 10
Sheep	5 00
Poultry	5 35

FACTORS INFLUENCING THE COMPOSITION OF MANURE

KIND OF ANIMAL

As has already been pointed out, the composition of manure varies with the kind of animal producing it. Sheep and poultry manures are much richer in plant food constituents than are horse, cow and pig manures, due largely to the character of the ration used.

Cow and Horse Manures.—The cow is the largest manure-producing animal on the farm and while its excreta is least rich in fertilizing elements, the large volume places it as the most important manure produced in mixed and dairy farming. Horse manure is distinctly richer in nitrogen, phosphoric acid and potash than cow manure but its open character makes it more liable to fermentation and unless carefully conserved it loses its valuable constituents quite rapidly. For this reason the best plan is to mix these two manures if they are to be left for any length of time in the pile.

Pig Manure.—Pig manure varies widely in composition and its value in plant food elements will depend largely on the character of the food consumed. Where the animal is well fed on high protein concentrates, i.e. tankage, meat meal, etc. and sufficient litter used to absorb all the liquid excreta the resulting manure should be fairly rich. The liquid portion of the manure of pigs fattened on a strong diet will contain a high percentage of nitrogen, sometimes as high as 1 to 2 per cent.

Less attention is paid to pig manure on the farm than to other manures and some farmers apparently are prejudiced against its use for certain crops. There does not appear to be any just reason for such an attitude on the part of the farmer as average pig manure may be considered somewhat richer than mixed cow and horse manure. However, as a general rule better results follow the application of mixed manures than from anyone singly.

Sheep Manure is a very rich manure, containing in its pure state about twice as much plant food constituents as cow manure. Owing to its more or less concentrated nature and the facility with which it can be distributed it has been found of special value for top dressing and for the enrichment of the soils of gardens, lawns, golf courses, etc. It is becoming common practice to artificially dry and pulverize the manure for the market.

Poultry Manure is undoubtedly the richest manure produced on the farm. In common with all other manures it has not a fixed composition, but the fact that the liquid and solid excreta are voided together as a moist mass insures against the loss from drainage of urine, unavoidable to some degree with the larger domestic animals, and explains in part its high nitrogen content. Another reason for its richness in nitrogen and phosphoric acid may be found in the character of the feed used. This is especially true with respect to laying stock, to which it is customary to feed meat scraps, green bone and similar products with high percentages of nitrogen and phosphoric acid.

The Division of Chemistry has recently analysed a series of samples of poultry manures, collected without litter or absorbent, produced on the Experimental Farm, Ottawa, obtaining results given in the following table:—

ANALYSES OF POULTRY MANURES, DIVISION OF CHEMISTRY, C.E.F.

Particulars	Water	Nitrogen	Phosphoric acid	Potash
	p.c.	p.c.	p.c.	p.c.
Laying Stock—				
Grain fed	74·6	1·12	0·97	0·52
"	72·3	1·11	0·88	0·49
" with green bone	72·6	1·42	2·01	0·42
Fattening Stock—				
Crate fed with milk	65·8	1·53	0·78	0·38
Yard fed with milk	74·3	1·31	1·C4	0·55
Average	71·9	1·30	1·15	0·47

From these data it may be concluded that, speaking generally, poultry manure, as collected beneath the roosts, is from two to three times richer in nitrogen and three to eight times richer in phosphoric acid, than the ordinary farm manures. On the basis that the excreta that can be collected beneath the roosts per annum per adult fowl, amounts to twenty-five pounds—a conservative estimate—the value of the plant food in the manure from a flock of twenty-five hens that can be obtained and employed for garden or field use, per annum, at present prices of the fertilizing elements, would be $2.30.

Poultry manure ferments very quickly, losing, if left exposed, a large proportion of its nitrogen as ammonia. This fact emphasizes the desirability of systematically and frequently cleaning off the boards beneath the roosts—a plan that also conduces to the general good health and thrift of the fowl. In summer the manure, previously mixed with loam to destroy stickiness and facilitate distribution, may be applied directly to the land and worked into the surface soil—its best preservative. In winter (and at other seasons if the manure cannot be directly used) it should be mixed with a fair proportion of loam, dried peat, muck or sawdust, together with a little land plaster or superphosphate to fix the nitrogen, packed tightly in barrels or boxes, and stored protected from rain until required in the spring. Lime and wood ashes should not be used for this purpose as they set free nitrogen.

Poultry manure being essentially nitrogenous is particularly valuable for garden and leafy crops generally and the majority of poultry keepers will no doubt do well to reserve it for this use. However, if the amount available permits, it can be profitably employed for the cereals, grasses, roots and corn.

Stockyard Manure.—At shipping centres the holding of stock results in the accumulation of large quantities of manure in the pens and yards. The manure so formed is largely from cows and steers. It is usually " short ", the litter consisting mostly of hay used in feeding the animals. It would be expected that stockyard manure would conform more or less closely in fertilizing constituents with ordinary cow manure.

A sample of stockyard manure obtained from the Alberta Stockyards, Calgary, Alta., was submitted to analysis in the laboratories of this Division. The sample as received was quite moist, containing 75 per cent of water, of a dark brown colour, apparently uniform, and would be regarded as " fresh ", decomposition changes or rotting not having taken place to any marked degree. In the following table the results of the analysis are given and for the sake of comparison the average composition of well-preserved cow manure as obtained from a number of analyses at the Experimental Farm, Ottawa is included.

COMPOSITION OF STOCKYARD MANURE

—	Nitrogen		Phosphoric Acid		Potash	
	Per cent	Pounds per ton	Per cent	Pounds per ton	Per cent	Pounds per ton
Stockyard manure..........	0·48	9·6	0·14	2·8	0·47	9·4
Average cow manure.......	0·57	11·4	0·14	2·8	0·49	9·8

In view of the foregoing data, fresh stockyard manure which has been formed with a sufficiency of litter may be regarded as comparing very favourably with fresh cow manure that has been well preserved.

Stockyard manure is sometimes sold as "Dried Manure." It is dried and sterilized and then screened and pulverized before it is put on the market—usually in 100-pound bags.

Samples of dried stockyard manure examined by the division include three different brands, viz. "Shredded" (coarsely ground), "pulverized" (finely ground), and "phosphated" (finely ground and mixed with superphosphate of lime). The analyses are as follows:—

ANALYSIS OF DRIED MANURE

—	Shredded	Pulverized	Phosphated
Water..........	7·27	7·54	5·05
Organic matter..........	73·69	67·22	50·55
Ash or mineral matter plus sand, etc..........	19·04	25·24	44·40
	100·0	100·0	100·0
Nitrogen..........	2·12	2·06	1·14
Phosphoric acid..........	1·54	1·49	8·70
Potash..........	1·47	1·81	1·47

These data would indicate that with respect to fertilizing constitutents, one ton of the shredded or pulverized brands is the equivalent approximately of from four to five tons of fresh mixed manure of good average quality.

In respect to sterilization it may be pointed out that this operation, if thorough and complete, may be both an advantage and a disadvantage. As an advantage it would presumably constitute a protection or safeguard against vital weed seeds and the dissemination of such diseases as may be transmitted by manure from affected animals. On the other hand, sterilization as an operation destroying all micro-organisms in the manure must be regarded as a disadvantage, since one highly important function of manure is to inoculate the soil with those bacteria which in the course of their development prepare the stores of inert soil plant food for crop uses. Sterilized manure must be valued largely, if not entirely, according to its plant food content and its ability to furnish humus-forming material—the latter undoubtedly a valuable property though not one to which a dollar and cent appraisement can be attached.

It is not at all probable that these "dried" concentrated manures will find a place in ordinary farm practice, but for the amateur city gardener, for market gardening, lawns, golf courses and other phases calling for intensive fertilizing it is evident that they will be found effective and convenient.

FOOD

This is one of the most important factors in determining the quality and value of manure. The quality of the manure is *chiefly* dependent upon the quality of the food consumed. The richer the food in albuminoids or flesh-

formers, the richer will the manure be in nitrogen. The same will hold good regarding phosphoric acid and potash. Again, the digestibility of the diet has much to do with the quality of both the solid and liquid excrement.

As showing this effect of diet upon quality and quantity of manure produced, the subjoined table may be inserted, containing results obtained at Rothamsted by Lawes and Gilbert. The figures are from an experiment with cows fed with mangels (a poor food) and lucerne or alfalfa hay (a feeding stuff rich in fertilizing elements):—

Fresh Manure per day	Mangels		Lucerne	
	Solid excrement 42 lb.	Urine 88 lb.	Solid excrement 48 lb.	Urine 14 lb.
	p.c.	p.c.	p.c.	p.c.
Water	83·0	95·14	79·70	88·23
Nitrogen	0·33	0·124	0·34	1·54
Phosphoric acid	0·24	0·011	0·16	0·006
Potash	0·14	0·597	0·23	1·690

The above data afford a striking illustration of the great influence of food. It may be safely inferred that manure from cattle wintered upon straw will not only be scanty as regards quantity, but also very poor in plant food. A liberal diet of nourishing food not only gives the best results as regards the stock, but also produces the richest manure.

As the quality and quantity of the solid food affect the amount and composition of the excrements, so does the amount of water drunk. The more water that the animal takes, the poorer or more dilute will be the urine, but the inferior quality will be " largely compensated for by the increased quantity voided ".

AGE

Young and growing animals absorb a much larger percentage of their food than do those that are mature or full grown, and consequently the manure of the former will not be as rich as that of the latter. Approximately, 50 to 75 per cent of the nitrogen, phosphoric, acid, and potash of the food consumed by young stock will be found in the manure and from 90 to 95 per cent in that of full-grown and fattening stock.

FUNCTION OF THE ANIMAL

Animals producing milk, wool, etc., make a greater draft upon their food than fattening stock or those animals which are at rest or working. Mature animals at rest return practically all the fertilizing constituents of their food in their excrements, whereas cows in milk utilize about 25 per cent of the plant food elements in their diet. The manure of fattening steers will therefore be much richer than that of cows producing milk, the food, litter, etc., being equal as to quantity and quality in both cases.

LITTER

The bedding material employed in stables and yards serves a dual purpose: it keeps the animals dry and comfortable and soaks up the liquid manure, preventing its loss through seepage, etc.

The quantity and quality of the litter necessarily affects the composition of the resultant manure. In the following table are given the approximate percentages of fertilizing constituents of the materials more commonly used for bedding purposes.

MANURIAL CONSTITUENTS OF LITTER

—	Nitrogen	Phosphoric acid	Potash
	p.c.	p.c.	p.c.
Straw	0·5	0·2	1·0
Sawdust and shavings	0·4	0·3	0·7
Peat moss	0·8	trace	trace
Muck and peat (air-dried)	1·5	"	"

Straw is the bedding material almost universally used on the farm. It will absorb from two to three times its weight of liquid. If the supply is scanty, it will pay to cut all the straw used as litter, for finely cut it will absorb about three times as much liquid as uncut.

Dry sawdust and fine shavings can be recommended as clean and satisfactory bedding materials. Their absorptive capacity according to fineness and dryness is from two to four times that of ordinary straw.

There is a more or less general impression among farmers that manure from stables and cowbarns in which sawdust has been used as a litter is injurious to the land. While we would not say that this suspicion may not have some foundation we have never been able to discover a single instance of such injury and enquiry has been made both in Canada and the United States in this matter. Such injury could only occur on very light soils following very heavy applications. Most satisfactory evidence has been obtained from many farms upon which sawdust has been used as a bedding material for a number of years and upon which the soil is light and sandy. Naturally it is on heavy soils that this class of manure proves most effective.

One word of caution is necessary. Horse manure from stables using sawdust heats very rapidly, especially if left in the pile, and the excessive fermentation that may take place will seriously injure the manure. Such manure should be mixed with that from the cowbarn, which can readily be managed when manure carriers are installed and a manure spreader used. Mixed manure (horse and cow) may be handled in the same manner as that made with straw. The saturation of the sawdust with the liquid excreta promotes the ready decomposition of the litter under favourable conditions of temperature and the best place for this to take place, in order that the full manurial effect may be obtained, is in the soil. If the manure cannot be spread at once, the heap should be kept moist and compact, as in the case of manure made with straw.

The sawdust of hardwoods, decomposes more rapidly and further is richer in potash and phosphoric acid than that of pines and conifers generally, but no harm due to resistance to decay need be feared from the use of the latter provided that it is not employed in larger quantity than is sufficient to absorb and retain the liquid excreta.

Peat moss, commonly known as moss-litter (sphagnum) makes admirable bedding; it is soft and absorbent. It will absorb about ten times its own weight of liquid and possesses the further advantage of being able to retain any ammonia that may arise from the fermentation of the manure in the stable or outside.

Muck and peat when air-dried make excellent absorbents. They are being used as such to good effect on many Canadian farms. Deposits of these materials are of no uncommon occurrence in many parts of the Dominion and their value in this connection is fairly well known. Digging and piling are all that is necessary. Their use generally is supplemental to the bedding proper, being found more especially valuable in the gutter behind the cattle, and in and about the farm buildings where there may be liquid manure or drainage to absorb. This employment of muck can be strongly advised, since thereby not only may a saving of much liquid plant food be effected at little cost, but the bulk and value of the resulting manure will be very considerably increased by the organic matter and nitrogen of this naturally-occurring fertilizer.

THE CARE AND PRESERVATION OF MANURE

Too great emphasis cannot be laid upon the necessity of caring for manures from the time they are voided until they are spread on the land; even with the best of care some loss is unavoidable particularly in the liquid portion. Losses may result from improper facilities for conserving the urine from excessive fermentation and leaching.

To save the urine at the outset the floor and gutter of the stable should be tight enough to prevent seepage. Concrete floors and gutters will be found most satisfactory for this purpose. Sufficient litter should be spread in the stall and in the gutter behind the stock to completely absorb all the liquid excrement. The importance of saving the urine of stock will be recognized since, as has been shown, more than one-half the nitrogen and at least three-fourths of the potash of manure is contained in the liquid portion, the fertilizing constituents of which being immediately available represents the most valuable portion of the manure.

From the time of voiding, decomposition of manure may take place quite rapidly, the rate of fermentation depending largely on the methods of handling, storing, etc. If left in a loose heap through which the air can permeate, fermentation takes place rapidly and serious losses of nitrogen by escape of ammonia may result. Particularly is this the case with horse manure and to a lesser extent with sheep and poultry manure. Horse manure, being of a looser texture and containing a larger proportion of undigested food, ferments more readily than cow manure. To prevent excessive losses through fermentation—fire fanging—the manure heap should be *kept compact and reasonably moist.* This may be accomplished when stored by allowing the animals to tramp over the manure in the yard or shed.

The use of preservatives such as gypsum, superphosphate, peat, etc., may help to a certain extent in preventing loss of nitrogen in the form of ammonia. When used for this purpose the material is usually scattered in the gutter and behind the stock; a valuable feature of their employment is that they keep the air of the stable pure and free from odours, and add appreciably to the value of the manure.

Losses through leaching occur when the manure heap is exposed to the action of heavy rains or if purchased from stockyards or livery stables, where the water hose is turned on it after it has been loaded on the railway cars. In districts of heavy rainfall, manure stored on the farm should be kept under cover if possible. The yard in which it is stored should have a cement or other impervious bottom such as puddled clay, to prevent seepage of the liquid portion and sufficient absorbent material such as straw, peat, etc. should be used to soak up the drainage.

When the drainings of a manure pile exposed to rain are allowed to run off and escape there is a great loss in the available and hence more valuable ele-

ments of plant food. Such "washed" manure is worth but a fraction of its original value. This depreciation due to fermentation and leaching before the manure is carted to the field may and frequently does exceed 50 per cent of its value as it came from the stable and cow barn. Reference has been made to the benefit to be derived from mixing the several manures, if they are to be kept for any length of time in the yard before application.

To illustrate the losses which may result through drainage the analysis of samples of the dark, almost black, liquid, draining from manure piles in four barnyards are given:—

COMPOSITION OF MANURE LEACHINGS

Fertilizing Constituent	In 1,000 parts			
	No. 1	No. 2	No. 3	No. 4
Nitrogen	0·511	1·14	1·60	0·03
Phosphoric acid	0·104	0·038	0·10	0·03
Potash	2·660	1·980	4·90	1·89

Experiments conducted by this Division at the Central Experimental Farm, Ottawa, in connection with the care and preservation of manure resulted in some very interesting information with respect to the losses of plant food constituents in the rotting of manure. The manure experimented with was composed of equal parts of horse and cow manure. Four tons of this mixed manure were placed in a weather-tight shed and an equal amount placed exposed in an outside box or bin, open to the weather, but with flooring and sides of wood in good condition and practically water-tight. These manures were weighed and analysed monthly for the period of a year. From the results of analyses the following data have been calculated showing the losses of fertilizing constituents that ensue under different systems of preservation.

LOSS OF FERTILIZING CONSTITUENTS IN THE ROTTING OF MANURE

—	At the beginning of experiment (fresh manure)	At the end of 3 months		At the end of 6 months		At the end of 9 months		At the end of 12 months	
		Protected	Exposed	Protected	Exposed	Protected	Exposed	Protected	Exposed
	lb.								
Weight of manure... lb.	8,000	2,980	3,903	2,308	4,124	2,224	4,189	2,185	3,838
Organic matter	1,938								
Loss in pounds	....	1,058	1,147	1,135	1,286	1,178	1,290	1,168	1,331
Per cent loss	....	55	60	58	65	60	67	60	69
Nitrogen	48								
Loss in pounds	....	8	14	9	15	11	19	11	19
Per cent loss	....	17	29	19	30	23	40	23	40
Phosphoric acid	25								
Loss in pounds	....	none	2	none	3	none	4	1	4
Per cent loss	....	"	8	"	12	"	16	4	16
Potash	62								
Loss in pounds	....	"	14	2	18	2	21	2	22
Per cent loss	....	"	22	3	29	3	34	3	36

These data show, that the chief losses take place during the first three months of rotting: that about 10 per cent more organic matter is destroyed in "exposed" than in "protected" manure; that nearly twice as much nitrogen escapes from the "exposed" than from the "protected" manure; and that while

the phosphoric acid and potash remain practically constant throughout in the protected manure, the losses of these elements, especially of the potash, are very considerable from the exposed manure.

The "exposed" sample in this experiment was rotted under much better conditions and circumstances as regards protection from loss by drainage than exist ordinarily upon farms. The losses from rotting manure upon farms in general must exceed many times those recorded here.

RELATIVE VALUE OF FRESH AND ROTTED MANURE

In the processes of rotting manure, fermentation decomposes the litter, the fertilizing constituents of which are rendered more or less available to plant growth, converts its nitrogenous matter and that of the solid excreta into substances that more readily form humus in the soil, increases to some degree the availability of the phosphoric acid and in all probability destroys the greater number of the weed seeds that may be present. However, even under good rotting conditions, there will be a loss of fertilizing constituents. Weight for weight rotted manure is more valuable that fresh manure, containing larger percentages of plant food and having these elements in a more available condition, but the losses in rotting may, and frequently do, out-balance the benefits. Unless there is some special reason for employing rotted manure the sooner the farmer gets his manure while still fresh into or onto the soil the better.

The following results give the average percentages of plant food in fresh and well rotted manure, respectively.

—	Pounds per Ton		
	Nitrogen	Phosphoric acid	Potash
Manure—fresh	7·8	3·6	9·0
" rotted	10·3	8·5	15·9

If for any reason it is desirable to rot manure in the large heap, the importance of keeping the mass compact cannot be over emphasized. Compactness and right degree of moisture are essential to reducing the losses to a minimum and the making of a manure of a high value.

With regard to the respective effects of fresh and rotted manures in different classes of soil it may be stated that fresh manure is better adapted for clays and heavy loams since it does much to improve their physical condition by opening them to the air and making them more friable. On the other hand rotted manure is better suited to light and sandy soils tending to make them more compact and retentive of moisture.

Fresh manure may with advantage be used for crops which have a long season of growth, while rotted manure, with its more available plant food will give better results for such crops as gather their food and reach maturity during a short period, and where early marketing is an important consideration.

METHODS OF APPLICATION OF MANURE

Losses of the valuable fertilizing constituents of manure through fermentation and leaching may be prevented to a large degree by hauling the manure to the fields as soon as possible after it is voided. Its best storehouse is the soil.

As far as may be practicable it should be immediately spread and incorporated with the soil. If there is no danger of surface wash, it may be spread and left on the surface of the land. The application is best done by the manure spreader. If season and soil conditions are such as to prevent this method of handling and distribution it may be piled in small heaps on the snow and spread in early spring. The latter method has the disadvantage that the snow is sometimes held longer where the heaps are located and the land is slower in drying out for seeding operations. On sloping ground the dressing of manure should be reserved until such time as it can be incorporated with the soil shortly following its application, or surface drainage may cause valuable constituents to be carried away.

Nitrogen enrichment of soil through the turning under of a legume crop.
Alfalfa: Showing extensive root system of second year growth.

CHAPTER III

GREEN MANURING

Green manuring is the practice of ploughing down a green crop or its aftermath. This results in returning to the land the plant food taken by the crop from the soil and also enriches the soil with a large amount of humus-forming material. Further, if the crop is a legume, e.g. clover, there is a possibility of adding 50 to 100 pounds, per acre, of nitrogen obtained from the air, which by its subsequent nitrification is converted into available plant food. The phosphoric acid, potash and lime may also be appreciably increased in the surface soil by this practice, since the roots of the clover plant extend much beyond plough depth and draw on the supplies of these mineral elements of plant food which ordinarily are below the reach of the roots of most crops.

The decay of the turned under crop in the soil also liberates its mineral constituents—phosphoric acid, potash, lime, etc.—in forms more readily available to crops than those in which they originally existed in the soil.

While as a rule a legume makes the most valuable crop to turn under as a green manure, other crops such as buckwheat or rye may be employed to good advantage, particularly when it is difficult to obtain a catch of clover or when the cost of clover seed is considered prohibitive. It is held by certain orchardists in Nova Scotia that buckwheat is a more satisfactory cover crop for apple orchards than clover. Though buckwheat does not materially enrich the soil in nitrogen, as does clover, it withdraws moisture from the soil at a time when the maturing of the wood is desirable and thus leave the trees in a better condition to withstand winter frosts.

It may be said therefore that the chief object in ploughing down a green crop is to enrich the soil in humus which is one of the most important constituents of all fertile soils. This results from the partial decay in the soil of roots, stems and leaves of the crop turned under.

FUNCTION OF HUMUS

Humus is the natural storehouse and conservator of nitrogen, which element is the most expensive of all plant foods when it becomes necessary to purchase it in commercial fertilizers. Where humus is abundant in the soil, it is associated with a liberal supply of nitrogen, and it has been noticed that the amount of humus present gives an excellent indication of the quantity of organic nitrogen the soil contains. It has also been observed that as the humus disappears the nitrogen goes with it.

Humus furnishes the food upon which the micro-organisms in the soil live. These convert its organic nitrogen into nitrates, the compounds which alone can supply crops with their nitrogen.

It contains also considerable quantities of mineral food constituents. These, in the further decomposition of the humus—a process continually going on in the summer when the soil is moist—are liberated in forms available to growing crops. In this way humus furnishes a large proportion of the potash, lime, etc., used by crops.

Humus increases the power of soils to absorb and hold moisture. This is a very important function. Since all the plant food furnished by the soil must be taken up in solution, the amount of water required by crops in their

feeding is enormous. For every ton of dry matter produced in plants, it is estimated that about 325 tons of water are required. Hence, several hundred tons per acre are needed for the growing of a single crop.

Humus regulates and protects against extremes of soil temperatures. It opens up and mellows heavy soils, while in the case of light loams it has a binding effect, increasing the moisture holding capacity of the soil.. Lastly, humus serves materially to diminish the loss of fertilizing elements by drainage, and thus affects further improvement.

WASTE OF HUMUS

Cultivation by ordinary farm methods, with plough, harrow, cultivator, etc., while most important and essential, exposes the soil to the action of the air and dissipates, to some extent, its humus. Further, the bacteria which are constantly at work in soils have their power as regards the oxidation of organic matter increased by the operations necessary to produce a good mechanical condition of the soil. This means not only a loss of organic matter, but also of nitrogen. Soils on which grain is grown year after year, lose, it has been found, much nitrogen by this oxidation of humus, and this loss is greatest in those soils which are richest in nitrogen.

INFLUENCE OF HUMUS ON THE MECHANICAL CONDITION OF THE SOIL

Though it may be stated that the chief function of a soil is to furnish certain elements for the nourishment of crops, it is equally true that in order to give the best returns, a soil must be fairly retentive of moisture, must contain air, and must form a firm and suitable support for the growth of plants and allow an easy foraging ground for their roots. Such a soil is said to be in a good state of culture or tilth.

Soils differ greatly in their character, not only chemically, but mechanically. The three chief types are light porous sands, heavy clays, and peaty soils. The most fertile loams are those in which the sand, clay and humus are present in proportions which result in a medium favourable to plant growth from the standpoint of fertility and tilth. When sand predominates, the soil is not so retentive of moisture, generally furnishes but a scant supply of plant food, and easily loses by oxidation and leaching a proportion of its most valuable constituents. Stiff plastic clays, which puddle in wet weather, and subsequently dry into hard lumps or masses, do not allow the air to permeate them or the growing roots to easily penetrate in search of the food they require. They may contain large quantities of plant food, but with such unfavourable mechanical conditions this food is of little value. Peaty soils are often sour (a property detrimental to farm crops), are not sufficiently heavy and compact, dry out readily, and lack mineral constituents. It is for the first two classes of soils that green manures may be used with the greatest benefit, for it is evident, whether sand or clay predominates, a certain proportion of vegetable matter is necessary to make the soil suitable for seed germination and to furnish that warm, moist aerated medium that is essential to luxuriant growth. A poor physical condition of the soil and a lack of sufficient moisture are qualities which follow the loss or absence of humus and they are factors which prevent the crops from utilizing, to the extent they otherwise would, such plant food as a soil may possess.

THE VALUE OF LEGUMES AS A GREEN MANURE

Legumes, such as clover and vetches, owe their popularity as cover-crops to the peculiar faculty, common to all plants of that family (*Leguminosae*), of deriving their nitrogen supply from the soil atmosphere by the aid of special bacteria which live in the nodules or tubercles on their roots. Where its practice is possible, green-manuring with legumes commends itself as a means of enriching the soil in humus, as well as of supplying a large amount of valuable nitrogen, the most expensive ingredient in commercial fertilizers.

Investigations by the Division of Chemistry revealed the fact that a vigorous crop of clover will contain, in its foliage and roots, approximately, per acre—

100 to 150 pounds of nitrogen,
30 to 45 pounds of phosphoric acid,
85 to 115 pounds of potash.

A single crop of clover turned under would thus furnish the soil per acre with an amount of nitrogen no less than would be supplied by 10 tons of manure. In soils possessing the nitrogen fixing bacteria it may be concluded that a very large part of the nitrogen in the clover has been obtained from the atmosphere and therefore on the turning under of the crop there is a distinct addition of this element to the soil.

The amounts of phosphoric acid, potash, and lime in the clover have, it is true, been derived entirely from the soil, but partly from depths beyond the reach of the roots of ordinary crops.

An experiment conducted by the Division of Chemistry, in respect to the enrichment of the soil by the growth of clover, gave results of such an interesting character that an outline of the work may well be repeated here.

The soil from a small plot was removed to a depth of 8 inches and replaced with soil thoroughly uniform throughout and containing 0.0437 per cent nitrogen. The mineral plant food constituents, phosphoric acid, potash, and lime were supplied at the beginning of the experiment. The plot was sown with mammoth red clover and kept in clover for a period of ten years. It was cut as occasion seemed to require throughout the season, not permitting the plants to go to seed, and the material was allowed to decay on the soil. Every second year the plot was dug over and resown. From time to time the soil of the plot was sampled and its nitrogen-content determined. The results are tabulated as follows:—

NITROGEN ENRICHMENT OF SOIL DUE TO GROWTH OF CLOVER

—	Nitrogen	
	Percentage in water-free soil	Pounds per acre to a depth of 4 inches
Before experiment	0·0437	533
After two years	0·0580	708
After four years	0·0608	742
After five years	0·0689	841
After six years	0·0744	908
After seven years	0·0750	915
After nine years	0·0824	1005
After ten years	0·0856	1044
Increase in nitrogen due to ten years' growth	0·0419	511

Thus it will be seen that over a period of ten years clover had enriched the soil to a depth of 4 inches with nitrogen to the amount of, approximately,

500 pounds per acre or 50 pounds per annum per acre. This nitrogen although not present in an immediately available condition is associated with readily decomposable organic matter and would be set free for the use of succeeding crops.

Many analyses of the clover crop have been made by this Division in connection with this nitrogen-enrichment investigation and the data show that the annual addition of nitrogen from this source in roots, stems, and leaves may vary, according to the season, character of the soil, the presence of nitrogen-fixing bacteria, etc., from 75 to 150 pounds per acre. If we assume that, in this plot, the growth of the clover annually added nitrogen at the rate of 100 pounds per acre, then half of this amount owing to oxidation, etc., was lost and the net gain was but 50 per cent of the initial enrichment. Cultivation of the soil involves a certain depletion of its nitrogen; this is inevitable, but unquestionably the loss from this cause is greater in light, open soils than in heavy, plastic loams.

THE INFLUENCE OF CLOVER ON CROP YIELDS

Experiments were conducted on the Central Experimental Farm in the early days—25 to 30 years ago—to determine in a practical way the value of ploughing down clover as measured by the increase in crop yields.

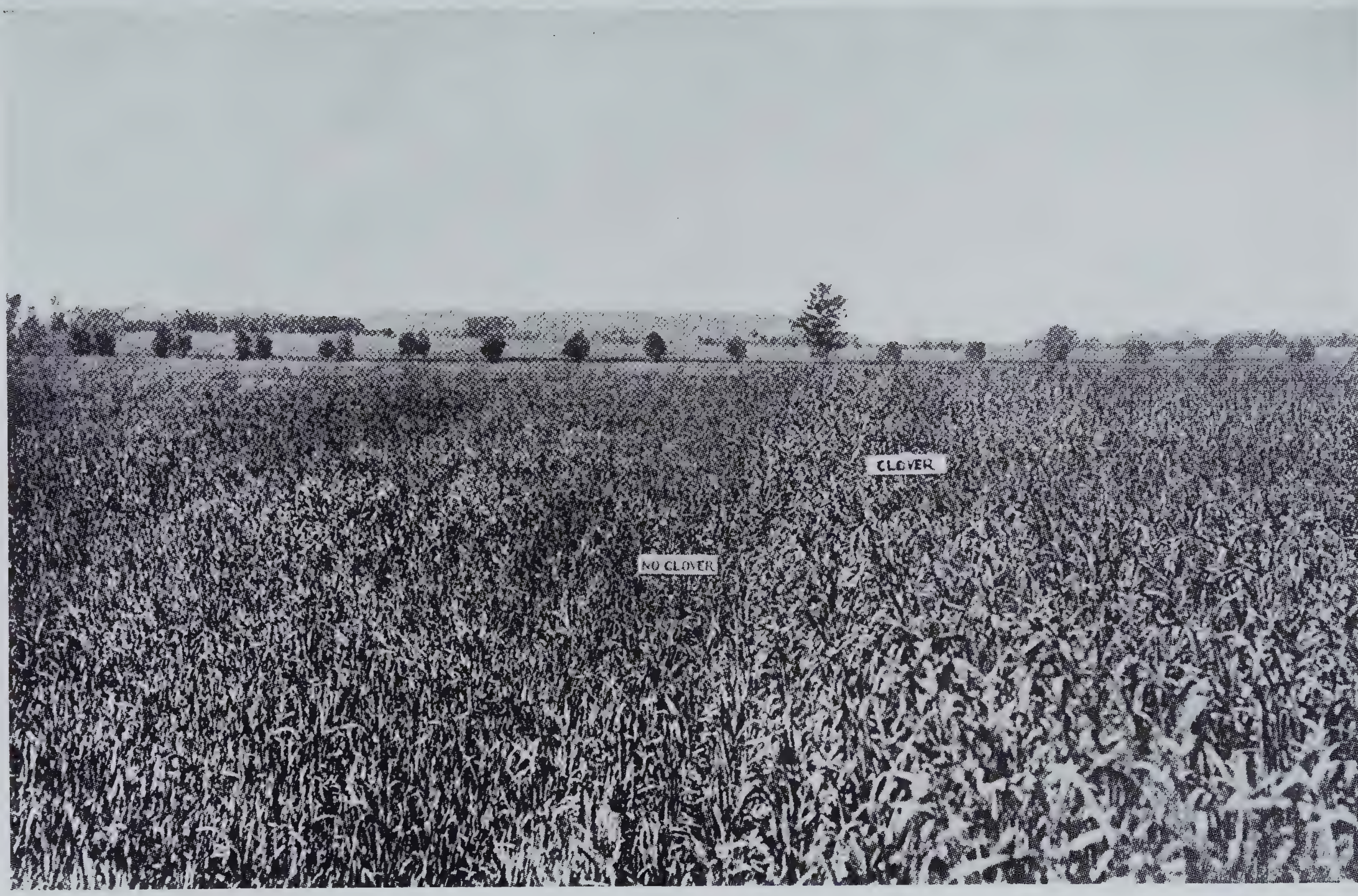
Clover was sown in the spring with wheat, barley, and oats in the proportion of 10 pounds of clover seed to the acre, duplicate areas being sown without the clover seed. By fall a good stand of clover resulted. When the next season's crop was to be grain, the plots were ploughed about the middle of October; where the land was to be used for corn or potatoes the following season, the plots were left until that spring before being ploughed. By the second or third week in May it had made a heavy growth and furnished a large amount of material for ploughing down.

The following tabulated data present briefly some of the results obtained in these investigations:—

INCREASE IN GRAIN YIELDS DUE TO CLOVER

Crop at Commencement of the Experiment, 1897	Yield of Oats 1898, per acre			Yield of Barley 1899, per acre		
	Straw	Grain		Straw	Grain	
	lb.	bush.	lb.	lb.	bush.	lb.
Wheat—Sown with clover	3,770	56	6	3,120	40	20
Sown without clover	2,160	37	2	1,740	25	20
Increase due to clover	1,610	19	4	1,380	15	0
Barley—Sown with clover	2,180	37	12	2,620	32	24
Sown without clover	1,450	30	10	2,440	27	44
Increase due to clover	730	7	2	180	4	28
Oats—Sown with clover	5,110	55	0	3,270	44	38
Sown without clover	2,260	44	4	2,320	33	36
Increase due to clover	2,850	10	30	950	11	2
Average increase due to ploughing under green clover	1,730	12	12	837	10	10

These results show that the ploughing under in the fall of a single crop of clover seeded with the grain in the spring produced a remarkable increase in both the straw and grain of the two succeeding grain crops. In 1898 there was an average increase of approximately 88 per cent of straw and 33 per cent of grain (oats). In 1899 the average increase was, approximately, 39 per cent of straw and 35 per cent of grain (barley). Undoubtedly these increases were due to the added fertility and humus supplied by ploughing under the crop of clover.



Fertilizing value of clover, oat crop after clover (right); oat crop after grass (left).—Central Farm.

Similar work to that already described for the grain crop was carried on with corn and potatoes, but in this instance the clover was not ploughed down until the latter part of May, when the land was prepared for the crop. The results from two years' trials—1900 and 1901, respectively—are given in one table as follows:—

INCREASE IN CORN CROP DUE TO CLOVER

Crop at Commencement of the Experiment (1899 and 1900)	Yield of Fodder Corn per acre in 1900 (Clover ploughed down May 24th)		Yield of Fodder Corn per acre in 1901 (Clover ploughed down May 22nd)	
	Tons	lb.	Tons	lb.
Wheat—Sown with clover	19	1,560	27	1,760
Sown without clover	16	1,160	19	1,280
Increase due to clover	3	400	8	480
Barley—Sown with clover	17	1,120	27	880
Sown without clover	16	1,440	15	1,600
Increase due to clover	....	1,680	11	1,280
Oats—Sown with clover	18	1,720	25	1,600
Sown without clover	14	1,800	20	160
Increase due to clover	3	1,920	5	1,440
Average increase due to ploughing under green clover	2	1,333	8	1,066

The average increase in yield of corn due to ploughing down clover in 1900 was 2 tons 1,333 pounds, or 16.6 per cent; for 1901 it was 8 tons 1,066 pounds, or 46.1 per cent.

INCREASE IN POTATO CROP DUE TO CLOVER

Crop at Commencement of the Experiment (1899 and 1900)	Yield of potatoes per acre in 1900 (clover ploughed down about May 24th)		Yield of potatoes per acre in 1901 (clover ploughed down May 22nd)	
	bush.	lb.	bush.	lb.
Wheat—Sown with clover	320	..	440	..
Sown without clover	280	40	396	40
Increase due to clover	39	20	43	20
Barley—Sown with clover	330	..	411	..
Sown without clover	280	..	381	20
Increase due to clover	50	..	29	40
Oats—Sown with clover	301	20	420	..
Sown without clover	290	40	396	..
Increase due to clover	10	40	24	..
Average increase due to ploughing under green clover	33	20	32	20

The average increase in the yield of potatoes due to ploughing down clover in 1900 was 33 bushels 20 pounds, or 11.8 per cent; in 1901 it was 32 bushels 20 pounds, or 8.3 per cent.

CHAPTER IV.

ARTIFICIAL MANURE

The term " artificial manure " has been applied to a product resulting from the treatment of straw by certain chemicals. The outstanding feature of the method is the conversion of straw into manure without being first used as a feed or litter for stock—the rotting down of the straw being brought about, as in the case of ordinary manure, by bacteria which in this process are nourished and encouraged by the chemicals added to the straw. These bacteria are ever present in the air and therefore there is no necessity to purchase or otherwise procure a special culture. In order to accomplish their useful work on the straw it is merely necessary that they should have a certain amount of soluble nitrogenous food (supplied by the chemical, sulphate of ammonia), moisture and air. The investigatory work which led to the devising of a practical process for making this artificial manure was carried out at the Rothamsted Experiment Station (England) during the latter years of the World War, when the general principles involved and more or less of the details of the process were discussed in the agricultural press by the authorities of that Station.

Following the experimental work at the Rothamsted Experiment Station the details of the process and of the materials used were placed in the hands of a commercial firm who undertook to place upon the market the necessary chemicals with the directions for their use. This reagent is offered for sale under the trade name of " Adco." The United States Department of Agriculture following up with experimental work the earlier published accounts of this method has made public that the addition of 100 pounds of ammonium sulphate and 100 pounds lime to each ton of straw, will give satisfactory results—a manure-like substance of a distinct fertilizer value. The materials—sulphate of ammonia and lime—may be scattered on the straw as it comes from the thresher, the straw being kept moist by a stream of water. If the straw is already piled or stacked the " manure " can be made by spreading on the ground a layer of straw—say, of two feet or thereabouts in thickness—and broadcasting over it the requisite amount of sulphate and lime, thoroughly moistening the mass and repeating the procedure until the heap has reached a height of, say, eight to ten feet, above which it is not convenient to work. If there are no ready means to renew the moisture from time to time and there is reason to think that the rainfall will not be sufficient to supply the water lost by evaporation, the heap should be covered with soil.

It is stated that the conversion of the straw into the resultant manure-like material will take from three to six months, that the loss of plant food during this period is less than that which takes place in the rotting of manure, and that this, " straw and sulphate " manure is practically equal in crop production to ordinary barnyard manure. But the evidence to date is necessarily limited and the whole matter cannot be said to have passed the experimental stage.

Essentially, this is a method for making humus—or a humus-like material—the nitrogen of which has been largely supplied by added sulphate of ammonia. It is a process which might have a practical value for the utilization of straw in districts in which it can be used neither as a feed nor a litter for live stock and in which climatic conditions are favourable to the rotting of straw. Market gardeners who have difficulty in obtaining stable manure and who must necessarily have a great deal of waste to dispose of, may find this method of preparing artificial manure from vegetable refuse quite useful and remunerative.

CHAPTER V

COMMERCIAL FERTILIZERS

Fertilizers are materials that furnish in more or less available forms, one or more of the three so-called essential elements of fertility—nitrogen, phosphoric acid and potash. When the material supplies all three, it is known as a " complete " fertilizer. Commercial fertilizers may be chemical compounds, such as nitrate of soda, superphosphate, etc., or they may be of organic origin such as bone meal, tankage, etc. Frequently the manufacturers use both classes of materials in compounding their ready mixed goods.

The primary function of a fertilizer is to furnish plant food in forms which are immediately available or which may readily become so in the soil. As previously pointed out, one of the main factors in determining crop yields is the amount of plant food in the soil which is available. When this is insufficient for a good growth it must be increased if maximum yields are to be obtained.

Character of soil, drainage and methods of working the soil as well as character of season—precipitation and its distribution, temperature, etc., are all factors which may profoundly affect the results obtained from fertilizer applications.

The employment of fertilizers is one of the chief means by which deficiencies of available plant food may be overcome. Too great a dependence must, however, not be placed on the use of these materials to rectify poor conditions of the soil possibly brought about by irrational farming practices. If best results are to be obtained from the use of fertilizers they must be considered as supplementary to manuring, to the growing of clover or other legumes and generally to good soil management including a satisfactory rotation. They cannot be used as a substitute for those means which science and practice alike have shown to be necessary for the economic up-keep and increase of soil fertility.

On soils which are naturally fertile, *e.g.*, many western Prairie soils, on soils which have had their fertility well maintained by the growth of legumes and the liberal use of farm manures, fertilizers may not and frequently do not give a profitable return. Occasionally, however, such soils being especially rich in nitrogen will be found to profitably respond to applications of phosphoric acid or potash or of both. Fertilizers can be used to greatest advantage on soils which are naturally deficient in available plant food or which have had their productiveness lowered by continued cropping without any concomitant return of plant food. In many districts in which the supply of manure is inadequate, the employment of fertilizing materials is practically imperative to successful farming.

It has been shown by carefully conducted experiments continued over a long period of years that the employment of fertilizers will permit a more economic and better distribution of manure on the farm. For example, it has been found on most cultivated soils, and especially on farms with a limited supply of manure, that better, *i.e.* more profitable results will be obtained by applying moderate dressings of manure supplemented by commercial fertilizer, than by the use of the manure alone at a heavier rate.

NITROGEN

Of the three so-called essential elements of plant food, nitrogen proves most frequently the limiting factor. The supply of available nitrogen in the soil determines largely the extent of plant growth and the ability of the crop to avail itself of other elements of plant food present.

As previously explained in the chapter on Soil Fertility, nitrogen more especially encourages a leafy growth, and excessive nitrogen in the absence of adequate supplies of phosphoric acid and potash may cause lodging and unduly delay ripening of the crop.

NITROGEN AND HUMUS

A knowledge of the conditions governing the supply of available nitrogen in the soil and its use by plants is useful as a guide to fertilizer treatment. The natural storehouse of nitrogen in the soil is humus, the partially decomposed organic matter derived from crop residues and farm manure. Soils deficient in humus are naturally unproductive, both from lack of nitrogen and of those desirable physical qualities which humus imparts.

NITRIFICATION AND AVAILABLE NITROGEN

Until it has undergone conversion into the nitrate form, the nitrogen present in the organic matter of soils, is unavailable to plants. The process of nitrification is performed by certain soil micro-organisms which attack, break down and change the organic matter to other forms.

In each of the various steps of the process leading to nitrification—e.g., from organic nitrogen to ammonia, from ammonia to nitrite and from nitrite to nitrate nitrogen—a special class of bacteria is engaged. These bacteria require for their development and activities, in addition to their food material, favourable degrees of moisture, air and heat.

In early spring, before the soil temperature has been raised to the degree necessary for nitrification, nitrates, even in some of the most fertile soils, will be very low and this fact explains the usually remarkable response of certain crops to early spring applications of nitrate of soda, a fertilizer which, as its name implies, contains its nitrogen in the immediately available nitrate form.

NITRATES LEACHED FROM THE SOIL

Nitrates formed in the soil in excess of crop requirements will, after the removal of the crop in the autumn, tend to be leached to the lower sub-soil layers and removed largely in the drainage water. It is especially the case in seasons of heavy rainfall. The downward trend of the soil moisture sets in with the colder weather in the fall, with the decline in the degree of evaporation which had hitherto promoted the upward capillary flow of the moisture. This leaching and removal of nitrate in the soil drainage is most pronounced in light soils with pervious subsoils in regions with heavy precipitation and especially from bare soils.

NITROGENOUS FERTILIZERS

Nitrate of Soda (15 to 16 per cent nitrogen), also known as Chile Saltpetre. As found on the fertilizer markets of the world this fertilizer is the crystallized and purified product from extensive deposits of the crude nitrate (caliche) occurring in Chile, South America. It is the most popular and quickest acting nitrogenous fertilizer. Its nitrogen is not only soluble in water but, being in the nitrate form, is directly and immediately available to the growing crop. The rapidity with which its nitrogen may be taken up by the crop renders this fertilizer particularly suitable for use in market gardens and as a supplemental top dressing to crops which may lack vigour, as indicated by a meagre growth of a yellowish colour.

Experiments have proved that the loss of nitrate nitrogen by leaching has been exaggerated. Little loss by leaching occurs during late spring and summer when a growing crop occupies the land. The greatest loss by leaching occurs in the fall, after the main crop has been harvested and hence the value of a catch crop.

Sulphate of Ammonia (20 to 21 per cent of nitrogen) is a by-product derived chiefly from the distillation of coal in coke ovens, blast furnaces, gas works, etc. It is usually slower in its action than nitrate of soda, for although its nitrogen is soluble in water it does not become available for use by plants until converted by nitrification into the nitrate form. However, under favourable conditions of moisture and tilth this takes place fairly rapidly, the more so as soil warmth increases.

Cyanamide (20 to 21 per cent nitrogen) is manufactured by the American Cyanamide Co. at Niagara Falls, by fixation of atmospheric nitrogen. It is the product of a process in which calcium carbide and nitrogen gas, when subjected to heat, etc., combine to form calcium cyanamide.

The application of cyanamide directly to the soil at planting time is apt to be followed by injury to the germinating seed; this injurious effect may be avoided by applying the material two to three weeks previous to the date of seeding. Cyanamide is chiefly used in the compounding of commercial fertilizer mixtures in which it is of value as a " conditioner ", and in the manufacture of " ammo-phos ", a high grade fertilizer furnishing nitrogen and phosphoric acid.

Nitrate of Lime (Calcium Nitrate) is a nitrogen fixation product and contains from 13 to 16 per cent of nitrogen. The results obtained from the use of nitrate of lime have been very satisfactory and as a rule much the same as those obtained from nitrate of soda. Its nitrogen appears to be equally available with that of nitrate of soda. On exposure to the air its property of absorbing moisture resulting in a wet material no doubt accounts for its comparatively small employment as a fertilizer. In recent years the deliquescent property of nitrate of lime has been overcome to some extent by treatment with oil. Its employment in Canada has been largely confined to experimental work.

Urea has recently appeared on the Canadian market and is sold under the trade name of " Floranid ". It is the most concentrated of all the nitrogenous fertilizers containing theoretically 46.6 per cent of nitrogen. Its availability appears to be much of the same order as that of the inorganic forms (nitrate and sulphate) and it is free from objectionable or harmful effects to seed or soil. Apparently, it can be used equally advantageously on all types of soils.

Ammonium Sulphate-Nitrate is another of the new nitrogen fertilizers and is sold under the trade name of " Leunasaltpeter ". Its total nitrogen content is about 26 per cent of which about one-quarter is in the form of nitrate nitrogen and three-quarters in the form of ammonium nitrogen. All its nitrogen is soluble in water.

Its recent introduction prevents any definite statement in regard to its relative value as a source of nitrogen but from its composition and properties it may be expected to give results comparable, per unit of nitrogen, with the more commonly used inorganic forms of nitrogen.

Ammonium Phosphate is a combined nitrogenous and phosphatic fertilizer sold under the trade name of "Ammo-phos". It has appeared on the Canadian market in two grades, viz., "13-48" grade containing 13 per cent ammonia (10.7 per cent nitrogen) and 48 per cent of phosphoric acid and a "20-20" grade containing 20 per cent ammonia (16.45 per cent nitrogen) and 20 per cent phosphoric acid. These are concentrated materials and have been found generally satisfactory as sources of nitrogen and phosphoric acid.

Dried Blood is a "by-product of the slaughter house consisting of animal blood treated under live steam, dried and ground." It is one of the most concentrated and valuable sources of organic nitrogen. Under favourable conditions of temperature and moisture it decomposes readily in the soil and the conversion of its nitrogen into available forms takes place quite rapidly. Two grades of dried blood, viz., red dried blood (12 to 16 per cent nitrogen) and black dried blood (6 to 12 per cent nitrogen, and 3 to 4 per cent of phosphoric acid were until recently used for fertilizing purposes, but the increased value of these products as stock feeds has resulted in a diminishing supply for use as a fertilizer. The material sold at the present time on the Canadian market must, according to the requirements of the Fertilizers Act, contain not less than 12 per cent of nitrogen.

Tankage "is a by-product of the slaughter house, consisting of animal tissue, blood, bone waste, organic matter or refuse treated under live steam, dried and ground. It must not contain less than 6 per cent of nitrogen and 6 per cent of total phosphoric acid." The materials used as fertilizer are the waste products which are not suitable for feeding stuffs purposes. Consequently tankage varies

Clover and Timothy Hay—Orchard Experiment—Kentville, N.S.

	Treatment per Acre		Yield of Hay per Plot, 1924
Plot No. 41	Nitrate of soda	150 lb.	152 lb.
	Acid phosphate	500 lb.	
	Lime	2 tons	
Plot No. 36	Nitrate of soda	150 lb.	168 lb.
	Slag	500 lb.	
	Lime	2 tons	
Plot No. 40	Check, not fertilized	....	36 lb.
Plot No. 39	Nitrate of soda	150 lb.	284 lb.
	Slag	500 lb.	
	Muriate of potash	150 lb.	
	Lime	2 tons	

widely in its nitrogen and phosphoric acid content and no product of a "standard" composition is to be found on the market. One of the most common types is the 6-15, *i.e.* 6 per cent nitrogen and 15 per cent phosphoric acid.

The greater part of the fertilizer tankage manufactured is used in the preparation of commercial mixtures, where it is valuable not only in supplying a portion of the nitrogen and phosphoric acid required but also to improve the physical condition of the mixture, *i.e.* it acts as a "conditioner" preventing "caking" or "hardening." The response from organic fertilizers of this type is much slower than that from the inorganic sources of nitrogen and for this reason they are considered as "slow-acting" and "lasting". Over a more or less long period of time they may be expected to compare favourably with the more available forms of nitrogen. Undoubtedly, the degree of conversion of tankage is dependent very largely on the nature of the soil and the character of the season.

Recent improvements in the process of manufacture of tankage have resulted in the reduction of the percentage of fat, the presence of which is very undesirable from the fertilizing point of view.

Ground Fish Scrap or Fish Meal "consists of fish tissue, fish bone and fish waste, dried and ground, and shall contain not less than 5 per cent of nitrogen and 5 per cent of phosphoric acid."

In districts bordering on the Atlantic and Pacific coasts ground fish scrap has proved a valuable source of nitrogen and phosphoric acid. In the manufacture of this material the offal—heads, tails, fins, entrails, etc.,—from fish canneries and in some cases the whole fish (dog-fish, menhaden) is used. The raw scrap is cooked with steam and then pressed, dried and ground for the market. This treatment removes the greater part of the oil, undesirable in a fertilizer, and makes a product which will keep on storage. Much of the fish meal manufactured is used in the preparation of mixed fertilizer.

The composition of fish scrap meal varies greatly, depending on the nature of the raw product and to some degree on the method of manufacture. Average fish meal manufactured for fertilizing purposes will contain from 6 to 8 per cent of nitrogen and from 5 to 8 per cent of phosphoric acid; when whole fish make up the major part of the scrap, *e.g.* dog fish, the phosphoric acid content may be as low as 2 per cent. The nitrogen and phosphoric acid of fish scrap become readily available in the soil.

Fish meal prepared from fresh and sound fish and fish wastes are used to a large extent for stock feeding purposes.

RELATIVE VALUE OF NITROGENOUS FERTILIZERS

The most widely used nitrogenous fertilizers are nitrate of soda and sulphate of ammonia and these two materials furnish the bulk of the nitrogen used in Canadian agriculture. Nitrate of soda, containing its nitrogen in the immediately available nitrate form, has in the past been accorded a relatively higher agricultural value than other nitrogenous fertilizers the nitrogen of which must first undergo conversion in the soil to the nitrate form in order to become assimilable. Repeated and heavy applications of nitrate of soda have a tendency to destroy good tilth of heavy clay loams owing to the alkaline residue left by this fertilizer.

Sulphate of ammonia is a particularly useful form of nitrogen for soils plentifully supplied with lime. It is specially suited for those crops which make their vegetative growth comparatively late in the season. It may and frequently does give results comparable with those from nitrate of soda. On the other hand the continued and exclusive use of sulphate of ammonia is not to be recommended on soils which have a low lime content since it tends to cause soil acidity. Applications of lime in one or other of its agricultural forms will naturally offset the tendency to acidity from the use of this fertilizer.

Recent work indicates the necessity of making a comparison of the unit prices of nitrogen in these two forms before the choice is made. In the very large number of experiments carried on by this Division the most profitable returns have resulted when both of these forms of nitrogen were employed.

Owing to their much greater value in late years as feeding stuffs, the organic forms of nitrogen, dried blood, tankage, etc.,—by-products of the packing house—are not used extensively as such in the fertilization of field crops; the greater part of these materials used for fertilizing purposes is employed in the preparation of mixed fertilizers and for market and garden crops. Naturally, these organic fertilizers are slower in their action than the inorganic (mineral) forms, *e.g.* nitrate of soda and sulphate of ammonia. The synthetic materials, nitrate of lime, urea, cyanamide ammo-phos, etc., have not, as yet, been extensively used in Canada and are more or less in the experimental stage in regard to their value as nitrogenous fertilizers.

PHOSPHORIC ACID

Phosphoric acid tends more particularly to promote the root development of the young seedlings in the early stages and the production of seed or fruit in the more mature stages of growth.

For the majority of crops grown on soils naturally low in plant food or which have become so through cropping, applications of a complete fertilizer containing a relatively high percentage of phosphoric acid have been found to give the most profitable returns. On well manured soils, *i.e.* soils rich in humus and nitrogen, phosphoric acid is most likely to be the needed element. On such soils, (which may contain an excess of nitrogen) it is of special value in promoting a strong healthy plant. In the case of cereals it produces a stiff straw, thereby tending to overcome "lodging."

Phosphoric acid has been found to hasten, in certain cases, the maturity of the crop, an important feature where the ripening is delayed by a cold and wet season and when the soil contains high amounts of organic matter, viz., mucks and peats.

Of crops which respond in a marked degree to liberal applications of phosphoric acid turnips and tomatoes are notable examples, the one valued for its large root development, the other for its fruit. Grain crops, particularly fall wheat, are usually benefited to a considerable degree by applications of this element.

PHOSPHATIC FERTILIZERS

Bones represent the oldest phosphatic fertilizers and are still employed largely in various forms.

Bone Meal (20 to 25 per cent of phosphoric acid and 3 to 4 per cent of nitrogen) results from the grinding of the raw bone.

The phosphoric acid in bone meal, although not immediately available, is, by reason of the decomposition of the bone in the soil, liberated gradually in forms utilized by crops.

Bone meal is frequently styled a "lasting" manure from the fact that its decomposition is necessarily slow. It gives its best results on soils which are warm, moist and rather light and well aerated. It owes its popularity in green-house work, undoubtedly, to the presence of these ideal conditions of soil, moisture and temperature. It further seems probable that here the chief beneficial influence is frequently due to the nitrogen of the bone meal, which is rendered available to the plants at a rate favourable to their rational development, under green-house conditions.

STEAMED BONE FLOUR (28 to 30 per cent of phosphoric acid and about 1½ per cent of nitrogen) results from the steaming or boiling of bone, under pressure, for the removal of the fat and the cartilage.

The loss of nitrogen in this process is to a very large degree compensated for by the higher percentage of phosphoric acid, the absence of fat which retards decomposition in the soil and the greater degree of fineness to which the material may be ground.

DISSOLVED BONES (BONE SUPERPHOSPHATE).—This material contains from 13 to 16 per cent of available phosphoric acid and from 1 to 2 per cent of nitrogen.

Sir John Bennet Lawes, founder of the world-famed Experiment Station at Rothamsted, England, instituted in the year 1834 experiments with bones as a fertilizer and found that by their treatment with sulphuric acid, part of the phosphoric acid in the bone was rendered soluble in water and therefore more readily available to plants. The name given to this product was "superphosphate." Later on, the discovery of the mineral (rock) phosphates furnished a new material which, treated in the same way, produced similar results, save, of course, that the product contained no nitrogen.

Dissolved bone or bone superphosphate is now rarely found on the market, but the term "bone superphosphate" is often erroneously applied to ordinary superphosphate.

SUPERPHOSPHATE (also known as acid phosphate).—This material according to the Fertilizer Act must contain at least 16 per cent of available phosphoric acid. This figure has become a standard but some brands contain as high as 17 to 18 per cent.

Superphosphate is the resultant product when raw phosphate rock is treated with sulphuric acid. By this process the greater part of the phosphoric acid of the rock phosphate is rendered soluble in water and, therefore, immediately available to plants. In addition to this water-soluble phosphoric acid, superphosphate, especially on long storage, contains a part of its phosphoric acid in a condition known as "citrate-soluble"—that is, soluble in a neutral solution of ammonium citrate. The "water-soluble" and the "citrate-soluble" (known also as "reverted") together constitute the "available" phosphoric acid. All superphosphates will contain also a small, variable percentage of insoluble phosphoric acid (from the presence of phosphate rock that has not been acted upon in the process), but this is not considered in estimating the agricultural value of the product; the "available" (water soluble plus citrate-soluble) phosphoric acid present fixes the value of any particular brand of superphosphate. The sulphuric acid, used in the manufacture of superphosphate unites with the lime displaced to form sulphate of lime or gypsum of which ordinary superphosphate may contain 40 to 50 per cent.

"DOUBLE" and "TREBLE" superphosphate (25 to 45 per cent of available phosphoric acid). These, as their names imply, may contain double or treble the amount of available phosphoric acid present in ordinary superphosphate.

The process by which they are produced is an expensive one, and, consequently these concentrated superphosphates are not often met with in Canada. But, where long haulage and high freight rates are encountered, they may yet become of considerable importance.

They contain little or no sulphate of lime or gypsum, the absence of which renders their drying out—subsequent to manufacture—more difficult than in the case of ordinary superphosphate.

AMMO-PHOS.—As previously pointed out under the discussion of nitrogenous fertilizers this material is a high grade fertilizer furnishing both nitrogen and phosphoric acid in an immediately available condition. (See page 34.) It is receiving considerable attention by the users of fertilizers in Eastern Canada.

Basic Slag or Thomas Phosphate Powder is a by-product in the manufacture of steel. The crude iron (pig-iron) contains small amounts of phosphorus and silicon which if allowed to remain in the steel make the latter brittle. This phosphorus and silicon is removed by lining the " converters " with lime which absorbs the phosphoric acid forming a basic phosphate. The slag on cooling forms a hard cinder which when finely ground possesses a very considerable fertilizing value. There are two processes used in the manufacture of steel, viz. Bessemer and Open Hearth, and the resultant slags vary very considerably in composition and content of phosphoric acid.

The requirements of the Fertilizer Act are that basic slag must contain at least 10 per cent of total phosphoric acid and that 80 per cent passes a 100 mesh sieve.

There is no Bessemer slag produced in Canada at the present time but considerable quantities are imported from Europe. The grade usually found on the market contains from 16 to 18 per cent of phosphoric acid of which 85 to 95 per cent is " available " by the official method of analysis for basic slags (Wagner).

Open Hearth slag is produced in Canada at Sydney, N.S., and usually contains from 7 to 10 per cent of total phosphoric acid. Since this is of too low a grade to put on the market its percentage of phosphoric acid has been raised by the addition of ground rock phosphate. This " fortified " slag is sold under the name of " Basic Slag and Florida Phosphate ", and contains from 14 to 20 per cent of phosphoric acid depending largely on the proportion of rock phosphate contained in the mixture. The availability of this product as measured by the official (Wagner) method is much below that of the Bessemer slags.

Two types or classes of Open hearth slag are recognized in Europe, viz., those made without fluor-spar and those in which fluor-spar has been used in its manufacture. The former are considerably the more valuable because of their higher solubility. The slag used in the manufacture of " fortified " slag is of the latter class.

Basic slag contains varying small proportions of free lime which gives this phosphatic fertilizer an additional value for acid soils.

Rock Phosphates.—Rock phosphate consists essentially of phosphate of lime and since it is used in large quantities in the manufacture of superphosphate, it plays an important role in agriculture. Large deposits of this mineral occur in Florida, Carolina, and Tennessee in the United States, in Nauru and Ocean Islands in the Pacific, and in Northern Africa. Native phosphate of lime as Canadian apatite occurs in Canada but it has not proved suitable for the preparation of superphosphate. More recently, phosphatic deposits have been found in British Columbia which if large enough, in time no doubt will be used in the manufacture of superphosphate.

The greater part of the rock phosphate mined in the United States is used in the making of superphosphate although a certain proportion of the ground raw rock is applied directly to the soil. The latter use in Canada of this United States mined material is not wide-spread due, no doubt, to the slow availability of its phosphoric acid in the soil.

Florida Rock Phosphate, known also as Floats or pebble phosphate, contains on the average from 28 to 30 per cent of phosphoric acid in the form of tricalcium phosphate (phosphate of lime) but occasionally deposits are found which contain as high as as 40 per cent. Its use in Canada as a direct application in the ground untreated form has been largely confined to experimental work. The Florida deposits are considered to be the most extensively worked of those in the United States.

Nauru Rock Phosphate, from deposits recently opened up on Nauru Island in the Pacific. A representative sample of this ground and untreated material recently analysed by this Division contained 32.0 per cent of phosphoric acid. Ground natural phosphate from the Nauru deposits has appeared on the market in British Columbia. Experiments to obtain data with respect to its effectiveness as a phosphatic fertilizer are being undertaken. Until such information is available no definite statement can be made in regard to the value of this particular material as a soil dressing in that province.

Ephos Basic Phosphate is ground rock phosphate prepared from deposits which occur quite extensively in Egypt. A representative sample of Ephos was analysed in these laboratories and found to contain 28.75 per cent of phosphoric acid. As efforts are being made to establish a market in Canada for Ephos, experiments have been instituted to determine its effectiveness as a source of phosphoric acid in comparison with superphosphate and basic slag.

With a view to obtaining some information as to the relative availability of the phosphoric acid in these several rock phosphates, laboratory experiments with certain dilute solvents have been made. Citric acid solutions of 1 and 2 per cent concentrations, respectively, have been employed, since these solvents have been used to indicate, approximately, the availability of the phosphoric acid.

ANALYSIS OF ROCK PHOSPHATES

—	Fineness. Percentage passing a 100-mesh sieve	Total phosphoric acid: 2 gm. boiled, with 30 cc. HCl 10 cc. HNO_3 and 50cc. H_2O (A.O.A.C.)	Percentage of Phosphoric Acid by different methods of analyses		
			5 gm. shaken 30 min. with 500 cc. of 2% citric acid solution (Wagner)	1 gm. shaken 30 min. with 500 cc. of 2% citric acid solution (Robertson)	1 gm. shaken 5 hrs. with 500 cc. of 1% citric acid solution (C.E.F.)
		p.c.	p.c.	p.c.	p.c.
Florida rock phosphate.......	72	29·58	5·89	18·62	20·03
Ephos basic phosphate*.......	98	28·75	10·76	27·66	25·67
Nauru rock phosphate.........	65	32·01	6·19	19·45	20·16

* The much finer ground product in the case of Ephos Basic phosphate, probably accounts, in a large measure, for the relatively high availability obtained.

RELATIVE VALUES OF PHOSPHATIC FERTILIZERS

The chief phosphatic fertilizers are superphosphate (acid phosphate) basic slag and bone meal.

Superphosphate is undoubtedly the most popular phosphatic fertilizer on the market to-day. The ready availability of its phosphoric acid enables it to exert its maximum beneficial influence during the first season. It is suitable for application to a large variety of soils, but is more particularly valuable as a source of phosphoric acid for soils well supplied with lime.

In the United States, superphosphate is more commonly known under the term " acid phosphate ". This usage has created an impression that the employment of this fertilizer induces an acid condition of the soil. Experiments have clearly shown that well made superphosphate does not contain any free acid and does not increase the acidity of the soil.

Basic Slag has been found to be an effective and profitable source of phosphoric acid in many parts of the Dominion. It has proved particularly useful in increasing the productiveness of heavy clay loams fairly well supplied with

humus, as from dressings of manure or turned under green crops. It has also been found of value for muck soils and soils deficient in available lime, both of which types are apt to be acid or sour, the response no doubt being due in part to the alkaline character of this fertilizer from the presence of a certain percentage of free lime and silicates of lime.

The phosphoric acid of basic slag is not immediately available but is liberated gradually, hence the effect of this fertilizer may be observed as a rule throughout the rotation. It has proved in the experimental work of this Division suitable for clover and timothy hay, turnips and mangels. When applied to grass lands it tends to bring in the finer grasses and encourages the growth of clover.

There are many brands of basic slag on the market and the purchaser should therefore carefully scrutinize the guarantee under which this material is sold. The phosphoric acid in Bessemer slag—known also as Thomas phosphate—is according to certain of our results more quickly available than that in Open Hearth Slags. " Fortified " slag—a mixture of Open-hearth slag and ground rock phosphate—is slower in action than Bessemer slag but over an extended period may be expected to give satisfactory returns.

Bone Meal.—As already noted, the value of this fertilizer is enhanced by its nitrogen content. Its phosphoric acid is not immediately available according to the accepted meaning of the term but is converted into forms usable by crops in the soil. The most rapid response is obtained when it is applied to warm, moist and moderately light loams.

POTASH

Of the three " essential elements of fertility " potash is more widely distributed and less frequently deficient in soils than nitrogen and phosphoric acid and may be considered the least important from the standpoint of the necessity of application. Clay loams as a rule are well supplied with potash and may not respond profitably to an application of a special potassic fertilizer. Indeed, upon heavy clays a too liberal application may depress the yield by bringing about an unfavourable condition of tilth. It is more particularly on sandy and gravelly loams, calcareous soils and soils rich in vegetable matter (as mucks and peaty loams) that this element may be expected to give a profitable return.

Again, it is not all crops that call for special potassic manuring. On the staple cereal crops, wheat and oats, potash seldom gives a remunerative return, save on the lightest and driest soils. Barley for malting purposes is to some degree an exception among the cereals, frequently responding profitably to potassic manures and particularly so on sandy soils.

Potassium performs certain vital functions in plant nutrition. The most important of these, it would appear, is related to and indispensable for the production and translocation of the carbohydrates—starch, sugar, and cellulose—within the plants. Hence it is that crops rich in these constituents—mangels, sugar beets, potatoes, sunflowers, corn, etc.—are those which are specially benefited by potassic manures. Fruits, large and small, and the leguminous plants—clover, pease, etc.—must be added to the list of those responding to potash. These are the crops, then, on sandy, gravelly loams, for which potash should be used, whether it be contained in a purchased fertilizer or one of the home sources as wood ashes, seaweed, etc.

POTASSIC FERTILIZERS

The greater part of the potash used in Canada for fertilizing purposes is imported in the form of muriate of potash, sulphate of potash, sylvanite and kainite from the Alsace-Lorraine deposits of France and the Stassfurt mines of Germany. During the year of 1924, there were brought in, approximately, 10,000 tons of these salts, of which about 95 per cent was in the form of muriate.

Muriate of Potash contains from 48 to 50 per cent of potash (K_2O) and is largely used in the manufacture of ready-mixed fertilizers, and by farmers and farmers' organizations in their home mixing of fertilizer materials. It is the most popular source of potash and is adapted for use on nearly all crops requiring a potassic fertilizer.

Sulphate of Potash contains approximately 50 per cent of potash (K_2O) and is preferred to the muriate for tobacco and sometimes for such special crops as potatoes, sugar beets, etc.

Sylvanite (20 to 30 per cent K_2O) and Kainit (12 to 14 per cent K_2O) are low-grade potash salts and their use has not become general in Canada.

Carbonate of Potash.—A by-product of the beet sugar industry, is used to a limited extent in Canada. It is quite variable in composition containing usually from 40 to 50 per cent potash (K_2O).

American Potash.—The exclusion of European potash during the war stimulated search for and exploitation of sources of potash on this continent with the result that potash was recovered from salt lakes in Nebraska and California, and as a by-product from certain industrial processes. At the present time the major portion of the potash produced in the United States is recovered from the brines of Searles Lake, California. This product contains from 50 to 58 per cent potash (K_2O) in the form of muriate of potash. Potash from American sources has not been used to any great extent in Canada.

Wood Ashes.—The ashes of wood have long been recognized as a fertilizer of very considerable value; indeed, their use in agriculture is historic. In all countries practising agriculture, including Canada, they have been highly prized, especially for clover, grapes and fruit trees and leafy crops generally, on sandy and light loams, and it was only with the advent of the German potash salts that their use fell off, though of course, their production in decreasing quantities of later years, owing to the disappearance of our forests, has been an important factor in making it more and more difficult for the farmer in the older settled districts to obtain them. Their potash is present essentially in the form of a carbonate, probably, the most acceptable form for use as a fertilizer. In good unleached, dry wood ashes, there may be present from 4 to 6 per cent of potash, about 2 per cent of phosphoric acid and from 25 to 35 per cent of lime.

Seaweed.—The use of seaweed as a fertilizer dates back to historic times and its value for the upkeep of soil fertility has been generally and practically recognized in both the old world and the new by farmers residing not too far distant from the coast line. Seaweed occurs on both our Atlantic and Pacific coasts (more abundantly probably on the latter) and may be collected in large amounts at little expense on many sea beaches, where it is thrown up by storms at times in prodigious quantities. It can also be collected in boats from rocks and floating masses not far from the shore. There are many varieties, some are quite small, others attain large proportions, but all are valuable, though naturally differing somewhat in composition.

Seaweed is essentially a potassic fertilizer, being specially rich in potash, but it also contains notable amounts of nitrogen and other elements of plant food, so that it might be termed a complete manure.

Analyses of many Canadian seaweeds, more especially from the Atlantic seaboard, have been made in the Experimental Farm laboratories at Ottawa, and certain of the data illustrative of their general composition are appended in tabular form.

ANALYSES OF SEAWEEDS COLLECTED ON THE ATLANTIC SEABOARD

—	Fucus furcatus	Fucus vesiculosus	Ascophyllum nodosum	Porphyra laciniata	Laminaria longicruris
Water	63·49	88·29	75·14	79·42	88·30
Organic matter	27·93	7·61	19·30	15·15	7·15
Ash or mineral matter	8·58	4·10	5·56	5·43	4·55
	100·00	100·00	100·00	100·00	100·00
Nitrogen	0·468	0·182	0·273	0·928	0·251
Phosphoric acid	0·108	0·037	0·070	0·068	0·134
Potash	2·025	0·615	0·619	0·619	1·546

Fresh seaweed is undoubtedly a watery manure, and it is this fact, no doubt —the cartage being a more or less expensive feature—that limits its use to those districts more or less close to the shore. A part of this useless water may be got rid of by piling the seaweed on the beach for a few days before hauling to the farm. But notwithstanding its large percentage of water, seaweed compares very favourably, weight for weight, with barnyard manure and it has this additional value that it brings to the farm no weed seeds or insects or fungus pests.

The essentially potassic character of seaweeds is well brought out by the analyses given, but it will also be noted that they are high in nitrogen. The differences in composition between the varieties may in part be accounted for by the stage of growth or maturity at the time of collection, and in this connection it is interesting to note that for several varieties collections made during the winter have shown a higher potash content than samples taken in summer.

The manurial value of seaweed is greatly enhanced by its ready decomposition in the soil; it quickly decays, liberating its constituents in forms available for plant nutrition. It is quite unnecessary to compost it, though little loss would ensue if composting with muck or other vegetable matter which would absorb and hold the decomposition products is resorted to, provided the heap is not exposed to heavy leaching rains. The weathering of seaweed alone is a wasteful process. On the whole, the best plan is to apply the seaweed direct to the soil, with which it readily becomes incorporated. It is essentially of the nature of a quickly acting, forcing manure.

Seaweed can be employed for all classes of crops, though it will be found most useful for roots, vegetables, and those plants with an abundance of foliage, since it is essentially a nitrogenous and potassic manure. It has given excellent results as a top dressing for grass lands, encouraging the growth of clover more particularly. Its composition suggests that if a more complete fertilizer is desired it should be supplemented by superphosphate, basic slag or bone meal, Seaweed gives its best returns on moderately light loams that are warm and moist and its poorest on wet, ill-drained, heavy clays.

RESIDUAL EFFECTS OF FERTILIZERS

The readily available nitrogenous fertilizers *e.g.* nitrate of soda, sulphate of ammonia, urea, are for practical purposes to be considered as effective only in

the year of their application. When these materials are applied to hay crops or when seeding down to clovers and grasses there may be a residual effect—an increase in yield in following crops—due to the decay and nitrification of the increased root system. Tankage and other forms of organic nitrogen are more "lasting"; their effect may be noticed over a number of seasons.

There is practically no loss of phosphatic and potassic fertilizers through leaching or dissipation and they may be expected to influence the crops throughout the rotation—three to four years or longer. With the readily available forms *e.g.* superphosphate, muriate of potash the maximum effect naturally occurs in the year of application. The slower acting materials—basic slag, bone meal, wood ashes while frequently exerting their greatest influence in the second and third years following their application may continue to beneficially affect crop yields over a more extended period.

In the following table the percentages of nitrogen phosphoric acid and potash in the more commonly occurring fertilizers are presented.

COMPOSITION OF THE PRINCIPAL FERTILIZER MATERIALS

Fertilizing Materials	Nitrogen	Phosphoric Acid		Potash
		Available	Total	
	p.c.	p.c.	p.c.	p.c.
NITROGENOUS FERTILIZERS—				
Nitrate of soda	15½			
Sulphate of ammonia	21			
Cyanamide	21			
Nitrate of lime	13–16			
Urea	46			
Ammonium sulphate-nitrate	26			
Dried blood	12			
NITRO-PHOSPHATIC FERTILIZERS—				
Tankage	6		15	
Fish scrap	6–8		4–8	
Bone meal	3–4		20–25	
Steamed bone flour	1–2		26–30	
Dissolved bone	1–2	13–16	15–17	
Ammo-phos—"13-48" grade	10·7	48		
"20-20" grade	16·5	20		
PHOSPHATIC FERTILIZERS—				
Superphosphate (acid phosphate)		16	18	
Double and treble superphosphate		25–45	30–50	
Basic slag			10–18	
Ground rock phosphate			25–35	
POTASSIC FERTILIZERS—				
Muriate of potash				48–50
Sulphate of potash				50–52
Carbonate of potash				40–50
Sylvanite				20–30
Kainit				12–14
Sulphate of Potash-magnesia				25–30
NITRO-PHOSPHO-POTASSIC FERTILIZERS—				
Tobacco stems	2–3		3–5	5–8
PHOSPHO-POTASSIC FERTILIZERS—				
Wood ashes (unleached)			1½–2½	4–6

When the standard fertilizer materials such as nitrate of soda, sulphate of ammonia, and superphosphate are purchased in their original containers it may be taken for granted that the material is as guaranteed.

The sale and registration of ready mixed fertilizers is controlled by the Fertilizers Act and the majority of manufacturers are making an honest and quite successful endeavour to meet the requirements of the Act with the result that most of the brands on the market are as guaranteed. However, if there is reason to suspect that a mixed fertilizer is below grade the purchaser may have it inspected by an official of the Seed Branch, Department of Agriculture which has the enforcement of the regulations under its control.

CHAPTER VI

FERTILIZER FORMULÆ AND HOME-MIXING

The composition of brands of commercial fertilizers is customarily expressed by formulae, such as, 2-8-2, 4-8-4, 4-6-6, 4-6-10, 5-7-7 etc. In each case the figures denote, in order, the guaranteed percentages of nitrogen, available phosphoric acid and potash, *e.g.* a 4-8-4 formula will mean that the fertilizer thus designated must contain actually 4 per cent of nitrogen, 8 per cent of available phosphoric acid and 4 per cent of potash.

ESTIMATING THE VALUE OF A FERTILIZER FROM ITS ANALYSIS

A knowledge of the current price per pound or *per unit* (20 pounds) of the plant food elements as procurable in the usual forms of nitrate of soda, superphosphate and muriate of potash will provide the farmer with a means of estimating the maximum commercial value of any fertilizer from its analysis.

The Unit.—In the fertilizer trade prices of nitrogen, phosphoric acid and potash are quoted usually at so much *per unit.* In this application a unit represents 20 pounds or *one per cent of one ton* (2,000 pounds). The unit thus means a definite amount (always 20 pounds) whether it be a unit of nitrogen, of phosphoric acid, or of potash.

In a ton of 4-8-6 fertilizer there are 4 units (or 80 pounds) of nitrogen, 8 units (or 160 pounds), of available phosphoric acid and 6 units (or 120 pounds) of potash. The use of the "per unit" prices simplifies calculations of fertilizer values.

In obtaining the approximate commercial value of a fertilizer the first step is to find the unit price of the three elements, nitrogen, phosphoric acid and potash. This is done by dividing the price per ton by the percentage of the plant food element present.

Assuming that nitrate of soda is worth $65 per ton and that it contains 15.5 per cent of nitrogen, the price per unit of nitrogen would be $65 divided by 15.5 or $4.20. Assuming that superphosphate is worth $20 per ton and that it contains 16 per cent of available phosphoric acid the price per unit of phosphoric acid would, by the same process be $1.25. Assuming that muriate of potash is worth $45 per ton and that it contains 50 per cent of potash the price per unit of potash would be $0.90.

Having obtained the unit prices of nitrogen, phosphoric acid and potash, the approximate value per ton of any mixed fertilizer may be readily determined by multiplying the number of units per ton by the price per unit, *e.g.*, in the case of a 4-8-6 mixture, as follows:—

——	Per cent or units per ton	Price per unit	Value of Ingredients
		$ cts.	$ cts.
Nitrogen	4 x	4 20	16 80 worth of nitrogen.
Phosphoric acid	8 x	1 25	10 00 worth of phosphoric acid.
Potash	6 x	0 90	5 40 worth of potash.
Total value	....	....	32 20 per ton.

While it is proper to allow a reasonable amount to cover the cost of mixing and bagging, it must be remembered that in no commercial mixture do the plant food substances possess a higher value than in those forms used in our illustration.

PREPARATION OF A FERTILIZER MIXTURE ACCORDING TO FORMULA

To simplify the calculations necessary when ascertaining how many pounds of the separate ingredients are required to prepare a fertilizer mixture having a certain formula, the following table may be used to advantage.

HOME MIXING TABLE

The following table shows the amounts of the fertilizer materials required in the preparation of One Ton of fertilizer to conform to any particular formula.

Percentage of plant food required—as expressed by the formula	Nitrogen supplied by: Nitrate of soda $15\frac{1}{2}$% N	Nitrogen supplied by: Sulphate of ammonia 21% N	Nitrogen supplied by: Dried blood 12% N	Phosphoric acid supplied by superphosphate (16% P_2O_5)	Potash supplied by muriate of potash or sulphate of potash (50% K_2O)
	lb.	lb.	lb.	lb.	lb.
1	130	95	167	125	40
2	260	190	334	250	80
3	390	285	501	375	120
4	520	380	668	500	160
5	650	475	835	625	200
6	780	570	1,002	750	240
7	910	665	1,169	875	280
8	1,040	760	1,336	1,000	320
9	1,170	855	1,503	1,125	360
10	1,300	950	1,670	1,250	400

Example No. 1.—To find the weights of the materials required to furnish the same amount of plant food as is contained in one ton of 4-8-6, using nitrate of soda, superphosphate and muriate of potash:

There is required 4 per cent of nitrogen. Opposite the number 4 (in first column) the amount of nitrate of soda to furnish 4 per cent of nitrogen is found to be 520 pounds.

Similarly, opposite 8 (in first column) the amount of superphosphate to furnish 8 per cent of phosphoric acid is 1,000 pounds.

Opposite 6 (in first column) the amount of muriate of potash necessary to furnish 6 per cent of potash is 240 pounds.

The balance required to make up to one ton in weight may be supplied by a filler (dry sand or fine loam, powdered peat or powdered land plaster) if desired to improve the keeping quality of the mixture or to facilitate an even distribution. The complete mixture then will be as follows:—

—		Plant Food Constituents per ton of mixture: Nitrogen	Phosphoric acid	Potash
		lb.	lb.	lb.
Nitrate of soda	520 pounds	80		
Superphosphate	1,000 "	....	160	
Muriate of potash	240 "	....	....	120
	1,760			
Filler (dry sand or fine loam, powdered peat or powdered land plaster)	240 "			
	2,000 pounds			

The filler may be omitted when immediate application is to be made; in this case the 1,760 pounds will contain the same amount of plant food as one ton of 4-8-6.

EXAMPLE No. 2.—To make up the equivalent of 4-8-6, using nitrate of soda and sulphate of ammonia to furnish the nitrogen in equal amounts:

From the above table it will be seen that 2 per cent of nitrogen is furnished by 260 pounds of nitrate of soda or 190 pounds of sulphate of ammonia. If superphosphate and muriate of potash are used to supply the phosphoric acid and potash the amounts are as follows:—

—		Plant food constituents per ton of mixture		
		Nitrogen	Phosphoric acid	Potash
		lb.	lb.	lb.
Nitrate of soda	260 pounds	40		
Sulphate of ammonia	190 "	40		
Superphosphate	1,000 "	....	160	
Muriate of potash	240 "	....	....	120
	1,690 "			
Filler (dry sand etc.)	310 "			
Total	2,000	80	160	120

For certain crops it may be desirable to use a certain proportion of an organic fertilizer viz. bone meal, tankage, etc. to furnish part of the nitrogen or phosphoric acid.

EXAMPLE No. 3.—For the preparation of a fertilizer with a formula 4-8-6 in which one-half the nitrogen is to be furnished by tankage and the other half by nitrate of soda, the procedure will be as follows:

In one ton of 4-8-6 there are 80 pounds of nitrogen, 160 pounds of phosphoric acid and 120 pounds of potash.

In 100 pounds of tankage which contains 6 per cent of nitrogen and 12 per cent of phosphoric acid there are 6 pounds of nitrogen and 12 pounds of phosphoric acid.

To furnish one-half the nitrogen (2 per cent or 40 pounds) there will be required $100 \div 6 \times 40 = 666$ pounds of tankage.

To furnish the balance of the nitrogen (2 per cent or 40 pounds) there will be required (see table) 260 pounds of nitrate of soda.

The 666 pounds of tankage will contain $12 \div 100 \times 666 = 80$ pounds of phosphoric acid. The balance of the phosphoric acid (160-80), 80 pounds may be furnished by superphosphate.

There are 16 pounds of phosphoric acid in 100 pounds of superphosphate (16% P_2O_5); therefore there will be required $100 \div 16 \times 80 = 500$ pounds.

The mixture will be:—

—		Plant food constituents per ton of mixture		
		Nitrogen	Phosphoric acid	Potash
		lb.	lb.	lb.
Tankage	666 pounds	40	80	
Nitrate of soda	260 "	40		
Superphosphate	500 "	....	80	
Muriate of potash	240 "	....	....	120
	1,666 "			
Filler	334 "			
Total	2,000 "	80	160	120

Example No. 4.—In districts where a long freight haul results in high prices for fertilizer materials due to transportation charges, the use of high analysis fertilizer mixtures may prove the most economical.

For example a 8-16-12 mixture may be prepared from nitrate of soda, ammo-phos and muriate of potash which will contain twice as much plant food as the 4-8-6. The following amounts of the above materials are required to make one ton of 8-16-12.

—		Plant food constituents per ton of mixture		
		Nitrogen	Phosphoric acid	Potash
		lb.	lb.	lb.
Nitrate of soda (15·5% N)	572 pounds	88·7		
Ammo-phos (13-48 grade containing 10·7% N. and 48% P_2O_5)	666 "	71·3	320	
Muriate of potash (50% K_2O)	480 "	....	....	240
Filler	282 "			
Total	2,000 "	160·0	320	240

There will be contained in ½ ton of this mixture 80 pounds of nitrogen, 160 pounds of phosphoric acid and 120 pounds of potash, which is the same amount of plant food that is contained in 1 ton of 4:8:6.

Example No. 5.—A mixture having a still higher analysis may be prepared using urea in place of nitrate of soda in the preceding example, as follows:—

—		Plant food constituents per ton of mixture		
		Nitrogen	Phosphoric acid	Potash
		lb.	lb.	lb.
Urea (46% N)	280 pounds	129		
Ammo-phos (13-48 grade containing 10·7% N and 48% P_2O_5)	1,000 "	107	480	
Muriate of potash (50% K_2O)	720 "	....	....	360
	2,000	236	480	360

The above mixture is approximately a 12-24-18 and one ton contains three times as much plant food as is contained in a ton of 4-8-6, or stated otherwise, 100 pounds of this mixture would equal 300 pounds of a 4-8-6 in plant food.

MIXING FERTILIZERS ON THE FARM

To the farmer who makes a practice of applying commercial fertilizers, it is often an advantage to purchase the separate ingredients and do the mixing at home. By this means he may not only save about 25 per cent in the cost of the mixed fertilizer but, knowing the source and availability of each plant food constituent, he is able to prepare the mixture in the quantities and proportions which from previous experience he believes will be best suited to the soil's requirements and the crops which he intends to grow. In addition, while the application of all three of the essential elements of fertility—nitrogen, phosphoric acid, and potash—will, as a rule, give the most profitable return, there are occasions when one or two of these three may be used advantageously, and at such times it is very convenient to have on hand a source of supply of each of these elements of plant food.

The operation of home-mixing may be simply and efficiently performed on the barn floor or other firm level floor by means of a shovel, a screen, and a mallet or wooden post to break the lumps.

Having assembled the sacks of materials from which the batch is to be prepared, empty the contents of each sack separately on the mixing floor. If the material has set in a hard firm mass, use the tamper or mallet to reduce the lumps before passing it through the screen, which should have about ten wires to the linear inch.

The lumps which are too coarse to put through the screen may be separately crushed and when reduced to a sufficient degree of fineness added to the heap.

Each component of the batch having undergone this preparation, its incorporation with the others may proceed.

The component—usually the phosphatic fertilizer—entering most largely into the mixture ought to be first spread on the floor, the others being superimposed in successive layers. The batch is then turned by shovelling first to one side and then to the other, for, say, four or five times. After turning once, the whole batch should be passed through the screen to ensure the absence of lumps and to facilitate mixing.

One ton is usually a sufficient quantity to mix in one batch.

It is, as a rule, desirable to apply the fertilizers to the land at once, or within twenty-four hours after mixing, in order that hardening or cementing of the materials may be avoided.

If it is known that the mixed fertilizers cannot be immediately used, it might be desirable to add a certain proportion of filler (fine dry loam or sand) for the purpose of checking this tendency to cake into hard masses after mixing.

Basic slag, wood ashes or other substances containing free caustic lime should not be mixed with sulphate of ammonia, as the lime by displacing the ammonia, causes its escape as gas and a loss in valuable plant food ensues. Basic slag is best applied unmixed with other fertilizer.

METHODS EMPLOYED IN THE APPLICATION OF FERTILIZERS

Where the areas to be fertilized are extensive the application may be performed by means of a broadcast sowing machine or drill, or by a special attachment to the seed drill. Certain seeding and planting machines are equipped with fertilizer sowing attachment designed so that the fertilizer is placed either above, below or to one side of the seed; of these three methods the side-dressing is considered the best. It is important that the fertilizer does not come into direct contact with the seed or potato set or injury to germination may result, especially under dry seasonal conditions. The safest and, perhaps, most generally satisfactory method of application of fertilizers is that of broadcasting and harrowing, which ensures more uniform distribution.

A method, simple and expeditious, may be found in the use of a two-handed sowing "hopper" or basket. This might be described as a crescent-shaped, canvas-covered frame with waist and shoulder straps attached. Both hands are used in sowing, and to obtain the proper rhythmical motion, it is necessary that the right hand be swung backwards from the hopper as the right foot advances and vice versa.

The size of the handful and the length of the stride may be regulated according to the rate of application desired.

Where the quantity of fertilizers to be applied is small—as, for instance, in top-dressings of nitrate of soda—in order to ensure uniformity of application, and to guard against burning of the foliage, it is desirable to increase the bulk of the fertilizer by mixing it with a quantity of sand or loose dry soil. Further when applying fertilizers as a top-dressing the leaves of the plants should be dry.

TIME OF APPLICATION

The opportune time at which fertilizer applications should be made will be determined to some extent by the nature of the crop, of the climate, and of the fertilizer materials employed.

Speaking generally, most of the phosphatic and potassic fertilizers should be applied during the final cultivation of the land preparatory to seeding.

The nitrogenous fertilizer may be applied at the same time, or when seeding, though some prefer to reserve a portion (assuming it to be in an immediately available form) for application as a top-dressing later on.

Phosphatic fertilizers, intended for fall wheat, should be applied in the fall, but soluble nitrogenous fertilizers, like nitrate of soda, should be applied to the wheat in the spring.

Immediately after their application to the thoroughly prepared land, the fertilizers should be incorporated with the surface soil by means of harrowing or light cultivating.

In the treatment of pasture and hay lands, the fertilizers should be sown in early spring. Basic slag, when used for this purpose should preferably be applied in the fall.

It seems desirable here to emphasize the fact that fertilizers cannot fully play their part in crop nutrition unless the soil is in good tilth. It should be mellow, warm, moist and well aerated, and these favourable conditions will be promoted by furnishing humus-forming material (as in barnyard manure), drainage, if necessary, and a thorough frequent working of the surface soil.

CHAPTER VII

FERTILIZER NEEDS OF VARIOUS CROPS

Chief among factors involved in a determination of the composition and quantity of a fertilizer designed to meet the specific requirements of a certain crop, are the nature of (*a*) the soil, (*b*) the climatic or seasonal conditions and (*c*) previous treatment of the land.

The Soil.—Clay soils are naturally more plentifully provided with the mineral plant food substances—phosphoric acid and potash—than are sandy soils. Muck soils, consisting essentially of vegetable matter, may often be almost devoid of mineral matter. These, though rich in organic matter and potentially rich in nitrogen, may still derive benefit from applications of farm manure, for the reason that manure contributes the bacteria which will ultimately, under conditions favourable to their development, promote the decomposition of the muck or peat, liberating therefrom plant food substances. In the fertilizer treatment of muck soils, phosphoric acid and potash, particularly, are important, though nitrogen also, in the form of nitrate may be desirable to encourage early growth.

Soil characteristics, as viewed externally, may not always be found reliable as a guide to the fertilizer treatment of crops to be grown thereon. For instance, it was found that of two light sandy soils, one (overlying a gravelly subsoil) responded in a very marked degree of potassic fertilizers, whereas on the other soil (overlying a silty subsoil) only a meagre response was obtained. This shows the necessity for discovering the peculiarities of each individual soil in order to practice fertilizer economy.

Climatic or Seasonal Conditions.—Moisture and temperature are potent factors in determining the size of the crop, and, incidentally, the kind and quality of the fertilizers that may be applied profitably. For example, certain potato growers in the Maritime provinces find it advantageous to apply a ton of fertilizer to the acre. In Western Ontario the maximum profitable application of a suitably compounded potato fertilizer would possibly be represented by not more than 1,000 pounds per acre.

The cooler, moister climate of the Maritimes is the factor above all which gives that province pre-eminence over many sections of Ontario in the yield of potatoes per acre. On the other hand, the warmer, dried climate of Western Ontario is more favourable to the growth of corn, alfalfa, fall wheat, etc.

Previous Treatment of the Land.—This may be considered chiefly in respect to manuring, fertilizing and cropping.

Speaking generally, when the soil has been enriched by liberal applications of manure the supplemental fertilizer may be smaller in quantity and need not contain such large proportions of nitrogen and potash as would be desirable where no manure has been, or is being, applied.

If for a preceding hoed crop a liberal application of fertilizers has been made, the succeeding grain crop—if it is deemed desirable to stimulate its early growth—may require only a small topdressing of a fertilizer supplying available nitrogen.

In deciding the nature of the fertilizer applications to be given, the draft made on the available plant food substances in the soil by foregoing "exhaustive" crops should be considered.

SUGGESTIONS FOR THE FERTILIZER TREATMENT OF VARIOUS FIELD CROPS

In view of the many factors involved, the futility of attempting, with any degree of precision, to prescribe "standard mixtures" for specified crops will be recognized.

The following suggestions are based on extensive experience in the use of fertilizers and on a knowledge of the special requirements of different crops and their varying abilities to procure the plant food substances.

The limit of profitable application of fertilizers will be determined by the value of the resultant increase in yield of the crop and further whether increases in the quantity of fertilizer applied are covered by corresponding increases in crop production. Thus, of a certain potato fertilizer, 1,500 pounds might be applied profitably in the Maritime provinces, whereas, in Ontario, any quantity in excess of 750 pounds might produce no additional increase in crop, or an increase insufficient to repay the cost of the extra quantity of fertilizer used.

The fertilizer formulae which follow are to be regarded as approximating normal requirements of the crop as grown on soils of medium fertility treated in accordance with ordinary farm practice.

For the sake of uniformity and for the purposes of comparison, the more usual sources (of constant high grade composition) of the plant food substances will be given in the formulae. Variations in this respect will be indicated in supplemental examples.

In the tabulated prescriptions the weight of each fertilizer component, *per acre,* is shown. Furthermore, assuming the addition of a certain quantity of inert "filler" to the mixture, and thus making it more on a parity with those found in commerce, the analysis (expressed in the usual formula) of the mixture is stated.

FERTILIZERS FOR GRAIN CROPS

Under a good system of farm management by which there is available an adequate supply of farm manure and in which the growing of legumes is included in the crop rotation the employment of commercial fertilizers for grain crops may not be necessary, though there are special cases in which phosphoric acid or nitrogen or both might be profitable. When the grain crop follows a hoed crop for which manure has been applied, or is sown on a legume sod ploughed under, the application of nitrogen seldom results in a profitable return, though phosphoric acid may be necessary for maximum returns. On every light sandy loams an application of potash may be desirable.

Under certain conditions and more particularly if the general fertility of the soil is low the application of one or more of the essential elements of plant food may be desirable, as follows:—

The soil may be lacking in only one element of plant food. For example in certain districts of eastern Canada it has been found that the soil is naturally deficient in phosphoric acid and applications of phosphatic fertilizers are usually followed by profitable results. Again, nitrogen may be the limiting factor calling for a dressing of a nitrogenous fertilizer.

When the soil is of low fertility naturally, or due to a limited manure supply or to heavy cropping, the application of a complete fertilizer mixture such as a 2-10-2 (or a 4-10-5 on light sandy loams) may be required for satisfactory grain production.

Poor growing conditions in early spring may warrant a top-dressing of a nitrogenous fertilizer such as nitrate of soda or sulphate of ammonia to encourage a more vigorous vegetative growth at that stage.

When seeding down with a legume and timothy the application of a complete fertilizer mixture (as above) for the nurse crop may ensure a good catch and benefit the following hay crop.

On muck and peat soils, phosphoric acid and potash are very often essential for good growth and satisfactory ripening of the grain.

The following is suggested as a liberal dressing of fertilizers for grain crops on soils of average fertility, the materials to be applied broadcast on the prepared land and harrowed in just previous to seeding; or they may be applied at seeding time by a special attachment to the seed drill.

FERTILIZER FORMULAE SUGGESTED FOR GRAIN CROPS

Character of Soil	Fertilizer Materials in pounds per acre			Equivalent (approximately) to
	Nitrate of Soda	Super-phosphate	Muriate of potash	
Light sandy loams	100	250	40	400 lb. of 4–10–5
Medium to heavy clay loams	50	250	....	400 lb. of 2–10–0
Muck soils	....	300	100	400 lb. of 0–12–12

Sulphate of ammonia may be used in place of nitrate of soda on soils well supplied with lime, and basic slag may be substituted for superphosphate to advantage on soils which are acid.

For *fall wheat* the superphosphate and muriate of potash should be applied in the fall at seeding time, and the nitrate of soda as a top dressing the following spring if the appearance of the crop indicates the need of nitrogenous fertilizers.

FERTILIZERS FOR HAY CROPS

The fertilizer treatment for hay crops will depend to a large extent on the previous treatment and cropping. When a four-year rotation of hoed crop, grain, clover hay, and timothy hay is followed, the clover crop (first year hay) may not require any further applications of fertilizers than that given to the first two crops of the rotation. (See section on Fertilizers for Grain.) Perhaps the most essential element for clover and alfalfa crops on the soils of eastern Canada, is lime. A deficiency of this mineral element results in an acid soil and a satisfactory growth of a legume crop is usually difficult to obtain. The application of lime (in the form of ground limestone, slaked lime, marl, etc.)—should be made before the nurse crop is sown.

On timothy hay, a top dressing of a nitrogenous fertilizer such as nitrate of soda or sulphate of ammonia frequently proves profitable when applied in one or more dressings at the rate of about 100 pounds per acre during the earlier weeks of growth. If a good rotation of crops has not been followed resulting in low fertility of the soil or if the soil is naturally of low productiveness a complete fertilizer mixture of the following nature may be justified:—

	Pounds per Acre
Nitrate of soda*	100
Superphosphate	150
Muriate of potash	40

* Sulphate of ammonia at 75 pounds per acre may be used in place of nitrate of soda.

FERTILIZERS FOR THE POTATO CROP

Of all ordinary farm crops that of the potato is probably the most profitably responsive to liberal feeding. The acceptance of this statement does not in the least ignore the fact that there are several other factors that play a very important part toward success in potato growing—type of soil, character of season and the cultivation and spraying of the crop—but it means that with these factors favourable the crop is a very responsive one to applications of

plant food and that the yield will be approximately commensurate with the available plant food supply.

It is generally conceded that there is no better preparation for this crop than a clover or alfalfa sod well manured (10 to 20 tons per acre) and ploughed in the late summer or early autumn. The practice of fall ploughing ensures the decay of the sod and manure and provides a good supply of humus, which is so useful in keeping the soil moist, and at the same time allows for the preparation of plant food in forms available for the use of the crop. Spring dressings of manure are not desirable, as they tend to encourage the development of scab. For the same reason applications of lime compounds should not immediately precede the potato crop.

On fairly good soil from a well manured sod as described, from 400 to 800 pounds per acre of, say, a 4-8-6 commercial fertilizer is to be considered a very liberal dressing. When manure is not to be had or if the soil is poor these amounts might be increased by one-half. In many of the potato growing districts of the Maritime Provinces, where fertilizers are relied upon to furnish the greater part of the plant food required for this crop, as high as 1,500 to 2,000 pounds per acre have been used with profitable results.

FERTILIZER FORMULAE SUGGESTED FOR THE POTATO CROP

(On average sandy loams)

Previous treatment of soil	Fertilizer Materials in Pounds per acre				Equivalent (approximately) to
	Nitrate soda	Sulphate of ammonia	Super-phosphate	Muriate of potash	
Clover sod liberally manured.	100	....	325	60	500 lb. of 3–10–6
Small dressing of manure......	100	80	400	100	800 lb. of 4–8–6
Clover sod—no manure........	100	80	500	160	1,000 lb. of 3–8–8
No clover or manure..........	150	120	600	190	1,200 lb. of 4–8–8

On clay loams the potash may be reduced slightly. On very light sandy loams it might be increased with profitable results.

FERTILIZERS FOR THE CORN CROP

Barnyard manure is the most satisfactory source of plant food for corn and on many farms the greater part of the manure produced is used for this crop. Manure contains relatively high amounts of nitrogen and potash as compared with its content of phosphoric acid; consequently it may be found advantageous to supplement the manure with a phosphatic fertilizer such as superphosphate. When the supply of manure is limited or if the soil is low in fertility a complete fertilizer in which phosphoric acid and potash predominate is to be recommended. On light sandy loams, potash is an important element of plant food for the corn crop, and unless the land is heavily manured, the application of a complete fertilizer having a fairly high content of potash may be desirable.

FERTILIZER FORMULAE SUGGESTED FOR THE CORN CROP

Character and Previous Treatment of Soil	Fertilizer Materials in Pounds per acre				Equivalent (approximately) to
	Nitrate of soda	Sulphate of ammonia	Super-phosphate	Muriate of potash	
Loams and clay loams—well manured......................	....	....	300	....	300 lb. of 0–16–0
Loams and clay loams—manure supply limited................	50	40	300	40	500 lb. of 3–10–4
Sandy loams—well manured....	35	25	300	60	500 lb. of 2–10–6
Sandy loams—manure supply limited......................	80	60	300	100	600 lb. of 4–8–8

In the above suggestions it is assumed that the fertilizer will be applied over the whole area as by broadcasting. If part of the fertilizer is applied broadcast and the balance in the row, or all is applied in the row the amounts given may be reduced somewhat. In the latter case care should be taken that the fertilizer does not come into direct contact with the seed. However, taking into consideration the benefit of the following crops that may be expected from the manure and fertilizer, the broadcasting method is to be recommended. In this respect attention is drawn to previous remarks on methods of application of fertilizer.

FERTILIZERS FOR MANGELS

The mangel crop responds to liberal manuring; for best results it requires a plentiful supply of available plant food in the early stages of growth. The employment of commercial fertilizers which furnish readily available plant food will aid greatly in giving the mangel plant an early start and in establishing itself in time to withstand periods of drought and the effect of adverse seasonal conditions which may occur during the later stages of growth.

While the nature and amount of commercial fertilizers best suited for the growth of any crop will depend, largely, on the character and general fertility of the soil, it should be kept in mind that the special requirements of the mangel crop are nitrogen and potash. Barnyard manure is most valuable in supplying nitrogen, phosphoric acid and potash, but the plant food of manure is liberated somewhat slowly and for this reason, larger yields are usually obtained if a moderate dressing of commercial fertilizer is used in conjunction with the manure.

On the average loam which has been dressed with manure at the rate of, say, 10 to 15 tons per acre, the following materials applied either broadcast or as a side dressing, at planting time, may be found to give profitable returns.

	Pounds per Acre
Nitrate of soda	125 to 250
Superphosphate	200 to 400
Muriate of potash	60 to 120
or (on soils well supplied with lime)	
Sulphate of ammonia	100 to 200
Superphosphate	200 to 400
Muriate of potash	60 to 120

Mangels—Fertilizer Experiment—Agassiz, B.C.

Left—Plot fertilized with nitrate of soda, 125 lb. per acre; superphosphate, 250 lb. per acre; muriate of potash, 125 lb. per acre. Right—Check, no fertilizer.

The above dressings are equivalent, approximately to 500 and 1,000 pounds per acre of a 4-6-6 ready mixed fertilizer.

On unmanured land larger dressings may be profitably employed, especially if the soil is low in fertility and of a sandy nature.

FERTILIZERS FOR TURNIPS

The fertilizing of the turnip crop has for a great number of years received special attention in Great Britain. It has been found that this crop responds particularly well to applications of phosphoric acid, which element of plant food favours root development and improves the quality. Turnips, as a rule, require a cool, damp climate and under such conditions may be supplied with fairly heavy applications of plant food, with profit. Under more or less dry conditions the yield may often be limited by the moisture supply and in these circumstances a small to moderate application of fertilizer will usually be found the most profitable. While the turnip crop responds in a very marked degree to an application of phosphoric acid, the addition of small quantities of a nitrogenous and potassic fertilizer in the manurial treatment will usually be found advantageous; it has been found that fertilizer dressings are particularly useful in forcing the development of this crop in the earlier stages of growth and thus, in a very large measure furnishing protection against the attacks of injurious insects.

Commercial fertilizers will, in most cases, give best results when used in conjunction with a dressing of barnyard manure. They may be applied broadcast or as a side dressing at planting time, but undoubtedly the safest and best results are obtained when the fertilizer is applied some little time—a few days—previous to planting and thoroughly incorporated with the soil to ensure diffusion in the soil.

For this crop, on average loams which have been dressed with 8 to 10 tons of manure, an application of from 300 to 500 pounds of superphosphate per acre may be found sufficient, or the following mixture may be used.

	Pounds per Acre
Nitrate of soda	100 to 150
Superphosphate	300 to 500
Muriate of potash	30 to 50

Equivalent, approximately, to 500 and 750 pounds per acre of a 3-10-3 mixed fertilizer.

When the crop is liable to an attack of "club-root" the soil should be previously dressed with lime, or if this cannot be done, the superphosphate may be replaced with advantage by an equal quantity of basic slag (lime compounds should not be used for this crop if it is the intention later on to grow potatoes on the same land). To reduce the risk of injury from "club-root" disease, the manure should be applied and worked into the soil the fall previous to the seeding. This practice will also serve a useful purpose in increasing the soil's absorptive capacity for moisture.

FERTILIZERS FOR TOBACCO

For the production of air-cured and fire-cured tobaccos of the best quality it is essential that the soil contains ample supplies of available plant food and that it is liberally supplied with organic matter or humus in an advanced stage of decay. These may be supplied in part by the growing of legumes and the use of manure.

On the average tobacco soil a complete fertilizer—containing nitrogen, phosphoric acid and potash—is needed. To obtain maximum yields and best quality these three elements must be present not only in sufficient amounts but in the proper proportion. An excess of nitrogen in the fertilizer may give a coarse dark late maturing tobacco while a deficiency of nitrogen may result in a thin small lightweight leaf. Phosphoric acid and potash should be present in ample amounts.

Of the sources of nitrogen for this crop sulphate of ammonia and nitrate of soda have given good results. Acid phosphate may be recommended as a source of phosphoric acid and sulphate of potash has been found most satisfactory to furnish the potash. Muriate (chloride) of potash should be avoided as it produces a leaf with a poor burn and a dark ash.

From the results of investigational work with fertilizers for the tobacco crop, carried on for a number of years the Tobacco Division suggests the following fertilizer mixtures.

For Flue-cured Tobacco (on average sandy loam soil)

	Pounds per Acre
Sulphate of ammonia	140
Superphosphate	600
Sulphate of potash	166

Equivalent approximately to 1,000 pounds per acre of a ready mixed fertilizer having the formula 3-9-8.

On extremely light sands it is suggested that the proportion of nitrogen and potash in the above mixture be increased and the equivalent of 1,000 pounds per acre of a 3.75-8-10 is recommended.

For Burley Tobacco

	Pounds per Acre
Sulphate of ammonia	400
Superphosphate	400
Sulphate of potash	166

Equivalent, approximately, to 1,350 pounds per acre of a 6-5-6 ready mixed fertilizer.

For Cigar Tobacco, Etc.

For cigar tobacco, the following mixture in addition to 15 tons of manure per acre has given excellent results:—

	Pounds per Acre
Nitrate of soda	225
Sulphate of ammonia	450
Superphosphate	600
Sulphate of potash	225

This would be equivalent approximately to 2,000 pounds per acre of a 6-5-6.

It is recommended that tobacco growers desiring detailed information with respect to fertilizing the tobacco crop communicate with the Tobacco Division of the Central Experimental Farm, Ottawa.

FERTILIZERS FOR SUGAR BEETS

There are a great many factors which influence the growth of the sugar beet; if conditions are unfavourable for its proper development, a successful and profitable crop cannot be had even though the crop is well fertilized. In the first place the seed of only such varieties as have been proved to be rich in sugar. should be grown. The soil must not only be fertile but its mechanical condition must be such that the roots easily penetrate it; the seed bed should be free

of stones and of good depth, to favour the development of a well formed root. A well drained soil is desirable particularly in the case of the heavier loams. Early sowing and thorough cultivation keeping the land free from weeds and the roots well covered with soil are other important operations in the culture of the sugar beet. The manurial treatment should be of such a nature as to encourage a rapid and continuous growth in the early part of the season and a satisfactory ripening of the beet in the later stages of growth.

The fertility and character of the soil will determine to a large extent the best kind of fertilizer to apply for sugar beets. When manure is available it should be applied either in the fall or to a preceding crop such as corn; when this is done, the application of from 300 to 400 pounds, per acre, of superphosphate will in all probability supply the plant food requirements of the crop.

When the supply of manure is limited or on soils of low fertility, a complete fertilizer is recommended, as for example the following:—

	Pounds per Acre
Nitrate of soda	100
Superphosphate	375
Muriate of potash	50

Equivalent to 500 pounds per acre of a ready mixed fertilizer having the formula 3-12-5.

Dressings of ground limestone or marl are recommended on soils which are deficient in lime.

The application of the fertilizer may be by broadcasting or in the row by an attachment to the planter. If the latter method is followed the machine should be designed so that the fertilizer does not come in contact with the seed. Where time permits it may be found advantageous to apply half of the fertilizer broadcast, and the remaining half along the row.

FERTILIZERS FOR MARKET GARDEN CROPS

In market gardening, the quality, earliness and yield of the products grown are determined largely by the rapidity of growth and development of the crop. Under favourable soil and climatic conditions, rapid and continuous growth will depend on the supply of available plant food in the soil.

The importance of well rotted manure in market gardening is well known; however, the decreasing supply of this fertilizer has led the market gardener to depend more and more on the use of commercial fertilizers to maintain the fertility of his soil. Bearing in mind the importance of a quick and continuous growth, the materials chosen for this branch of agriculture should be those which readily yield up their elements of plant food, or those in which the major portion of plant food is more or less quickly available to the growing plant.

On the average loam, enriched by a fair application of manure, the following mixture may be suggested as a generally useful fertilizer for garden crops:—

Fertilizer for Market Garden Crops (one ton mixture)

	Pounds
Nitrate of soda	320
Sulphate of ammonia	230
Superphosphate	1,250
Muriate of potash	200
	2,000

Equivalent approximately to 1 ton of 5-10-5. The rate of application of this mixture will depend largely on the crop and fertility of the soil. From 500 to 800 pounds per acre might be considered a fairly liberal dressing.

On very light sandy loams, a mixture containing a higher percentage of potash may be desirable. For leafy vegetable crops such as cabbage, lettuce, etc., applications of a nitrogenous fertilizer by top-dressing may prove beneficial.

Some market gardeners, when a suitable manure is not available in sufficient amount, prefer to use a fertilizer containing relatively large quantities of organic materials.

Cabbage—Fertilizer Plots—Central Experimental Farm, Ottawa.
Left—Check plot, no fertilizer. Right—Plot fertilized with 1,000 pounds of 4-8-5 per acre.

A ton mixture of 5-10-5, containing both tankage (8 per cent nitrogen and 8 per cent phosphoric acid) and bone meal (3 per cent nitrogen and 25 per cent phosphoric acid) may be prepared from the following:—

	Pounds
Nitrate of soda	330
Tankage	500
Bone meal	300
Superphosphate	530
Muriate of potash	200
Filler	140
	2,000

Owing to the demand for meat and bone by-products as a stock food, the cost, per pound, of nitrogen and phosphoric acid in organic materials—tankage, bone meal, etc.—may be considerably higher than in the inorganic forms—nitrate of soda, superphosphate, etc.

For detailed information regarding the fertilization of market garden crops see Bulletin No. 32, "The Manuring of Market Garden Crops."

FERTILIZERS FOR THE APPLE ORCHARD

Unlike field crops, which have an annual habit of growth and must develop their root, stem, branch and, sometimes, fruit all in a single season, the apple tree has a permanently established root system, trunk and superstructure. Its widely ramifying roots penetrate to a considerable depth and are ready to draw nutriment from an extensive soil area, as these are rendered available for absorption.

As a result of lengthy and extensive research it has been found that fruit spur growth and fruit production are influenced in a marked degree by the supply of available nitrogen in the soil. The practice of applying nitrogen in the form of nitrate of soda at rates varying from 5 to 8 pounds per tree (200 to 300 pounds per acre) about three weeks before blossoming time is becoming general in the orchards of the Annapolis Valley in Nova Scotia.

However, the continued use of a nitrogenous fertilizer alone for the apple crop may result in too great a growth of wood and it would appear to be a safer plan to apply a complete fertilizer supplying phosphoric acid and potash in addition to the nitrogen.

If the trees are making fairly satisfactory growth the following fertilizer mixture may be found to meet the needs of the crops.

	Pounds per Acre
Nitrate of soda	150
Superphosphate	300
Muriate of potash	50

If the trees are not making a good growth the above rate might be doubled for a time until a vigorous growth is obtained.

When apple trees are grown in sod without cultivation, double the amount of nitrogen advised above may be used to advantage.

The preceding suggestions in respect to the nature and amounts of fertilizers for the crops mentioned are offered as a guide. Before purchasing fertilizers on a large scale, farmers who have had little or no experience in regard to the use of these materials are advised to conduct a certain amount of experimental work in order to determine the fertilizer or combination of fertilizers best suited to local conditions of soil and climate.

The Division of Chemistry (Experimental Farm, Ottawa) will be pleased to advise farmers in respect to these preliminary field trials and to conduct such analytical work on soils as may be necessary for the solution of special soil fertility problems.

CHAPTER VIII

SOIL AMENDMENTS

LIME

As previously pointed out in the chapter on Plant Food and Soil Fertility, lime ranks next in importance to potash and phosphoric acid in a consideration of the mineral constituents of plant food. In addition to its function of supplying plant food, lime is valuable in correcting acidity, in improving tilth and in promoting nitrification. Lime and its compounds are to be regarded primarily as soil amendments, i.e., materials that may improve the soil chemically, physically and biologically and thus make it more suitable for crop growth. Their value for many of the soils of Eastern Canada deficient in lime has been clearly demonstrated by investigational work conducted during the past ten years.

SOURCES OF LIME

Quick Lime, known also as quicklime, burnt lime, caustic lime, stone lime, etc., is produced from the burning of limestone (carbonate of lime) with wood or coal. The burning may be performed either in a specially constructed kiln or by the simpler method of heap-burning. The intense heat decomposes the carbonate, carbonic acid gas being driven off and caustic or quicklime remaining.

Slaked Lime, known also as hydrated lime, results from the union of water with quick lime. The process of slaking, or adding water to the lime, is commonly practised by builders in the making of mortars, and is accompanied by the generation of a considerable amount of heat. The result is a whitish-grey or greyish-white (according to the quality of lime) powder having properties that are distinctly caustic and alkaline. The heap of lime in slaking swells to nearly double its original bulk and a bushel of freshly-slaked lime will weigh approximately 40 pounds, as compared with 70 pounds per bushel, which may be taken as the average weight of lime. The weight of lime, however, may vary between 60 and 100 pounds per bushel, according to its degree of purity and the thoroughness of burning. This fact furnishes an argument in favour of purchasing lime and lime compounds by weight rather than by measure.

Air-slaked lime results from the long exposure of quicklime to the air. The lime first absorbs moisture, being converted into the hydrate (slaked lime), which then takes up and combines with the carbonic acid gas of the atmosphere to form the carbonate. Slaked lime, therefore, is variable in composition; it may be essentially slaked lime with a small percentage of carbonate, or largely carbonate of lime with traces only of slaked lime, depending chiefly upon the duration of the exposure.

Ground or Crushed Limestone is essentially carbonate of lime. Limestones are not all identical in composition; some contain notable amounts of carbonate of magnesium and are known as magnesian limestone or dolomite; others contain varying proportions of inert rock material. Hence the higher grades of limestone used in agriculture may be almost pure carbonate of lime, while the lower grades may contain less than three-fourths of their weight of carbonate.

The quality of a crushed limestone and its suitability for employment will depend on its chemical composition and its degree of fineness. A good quality

limestone will contain at least 80 per cent of carbonate of lime—or of mixed carbonate of lime and magnesia, as occurring in dolomitic limestones—while those of highest grade will contain 90 per cent and over.

The degree of fineness will determine to a great extent the rate of solution of the ground limestone in the soil and hence the rapidity with which it will correct acidity and furnish lime for plant growth. The finer the limestone the more rapid will be its solution and hence its effectiveness. Generally speaking, if a quick prompt action is desired a material 60 to 75 per cent of which passes a sieve 80 meshes to the linear inch will be found fairly satisfactory. If an immediate action is not of first importance a coarser ground limestone, say, 50 to 75 per cent passing a 60-mesh sieve can be successfully used. In any case, all should pass a 10-mesh sieve.

Marl or shell marl is a naturally-occurring deposit consisting essentially of carbonate of lime mixed with varying amounts of clay, sand or other inert material.

Some marls are almost pure carbonate of lime, others are more or less impure from the presence of clay, sand or organic matter, etc., as already noted, and these, of course, are of less value agriculturally. A marl, containing in the air-dried condition from 80 to 90 per cent of carbonate of lime may be considered of good average quality.

Usually, as found, marls are soft and pasty in consistency, frequently showing many small shells. On air-drying by simple exposure they are found to be readily friable, breaking down to a coarse powder which easily permits of uniform distribution on the land. It is seldom that the air-dried material will require any preliminary crushing; it therefore constitutes a very cheap and desirable source of lime, as not infrequently marl may be had for the cost of digging and hauling.

"Indurated" marl is a hard rock-like material with a honey-combed structure. It occurs by a deposition from the waters of streams and springs which are rich in carbonate of lime. Large deposits of this material occur in many of the valleys of British Columbia and are composed almost entirely of pure carbonate of lime. A certain amount of crushing is necessary before this type of marl can be used satisfactorily as a soil dressing.

ACIDITY OR SOURNESS

Lime and carbonate of lime combine with and neutralize the soil's acids and the excess used renders the soil slightly alkaline—a condition favourable to the growth of the larger number of farm crops.

Wet, low-lying and ill-drained soils are especially apt to become sour. Soils consisting essentially of vegetable organic matter, as mucks and peat loams, are usually, though not invariably, sour. Many light upland soils are slightly acid, presumably by the washing out and leaching away of their original store of carbonate of lime or its withdrawal by many years of cropping.

In all soils in humid districts, but more especially in sandy and gravelly loams, there is a tendency for the lime compounds to disappear, partly through removal by crops but more particularly by their solution (in water containing carbonic acid) and passage into the strata below the root area.

METHOD OF TESTING FOR ACIDITY WITH LITMUS PAPER

A commonly used test for soil acidity is blue litmus paper, which may be purchased at any drug store. It should be kept in a clean, dry, preferably wide-mouth well-corked bottle. When tearing or cutting off a strip of litmus paper for use, a pair of forceps or scissors should be used, as the paper is sensitive and the fingers may cause its reddening. The following test, if carefully carried out, is reliable.

Take up, by means of a clean spade or trowel, a little of the surface soil from, say, half a dozen places on the area to be examined and mix well; do not handle the soil. Take a small quantity (a few ounces) of the sample, put it in a clean cup or tumbler, pour on a little boiled water and stir with a clean piece of stick or spoon until a pasty mass is obtained. Into this "mud" press, by means of a small stick or the back of a knife, a strip of blue litmus paper for about one-half to two-thirds of its length. If on drawing out the paper, at the end of fifteen minutes, the part in contact with the soil has turned red, the soil is acid.

Recently, several equipments for determining the degree of soil acidity in the field have come into use. One of the simplest of these is "Soiltex," an outfit usable by farmers by which the degree of acidity is indicated, approximately, by the colour produced when the soil is moistened with a few drops of the indicator —a solution of brom-thymol blue—furnished in the outfit. The colour obtained is compared with the colour chart supplied, from which is read the soil reaction and the amount of lime recommended.

INFLUENCE OF LIME ON TILTH

The influence of lime and its compounds upon the tilth or texture of the soil is most marked in the case of clays, which it renders less sticky and cohesive when wet, and more friable and mellow when dry. On light soils—sandy and gravelly loams—lime and carbonate of lime exert a beneficial influence, their action being to cement slightly the soil particles, rendering the soils somewhat heavier and more compact in texture and, thus, less liable to dry out in seasons of drought.

INFLUENCE OF LIME ON THE BACTERIAL LIFE OF THE SOIL

The humus or semi-decayed organic matter in the soil is the main source and storehouse of nitrogen, the dominant and most costly element of plant food. Before this humus-nitrogen can be utilized by growing crops it must be oxidized and converted into nitrates. This process, known as nitrification, is the life work of certain vegetable micro-organisms or bacteria within the soil. In soils deficient in carbonate of lime, and especially in ill-drained, water-logged soils, the decay of the organic matter is accompanied by the development of certain organic acids, and thus the soil becomes sour. This acid condition of the soil is distinctly unfavourable to the life and development of the useful nitrifying organisms, for these can flourish only in a neutral, or slightly alkaline soil. Lime and carbonate of lime neutralizes these acids, making the soil a suitable medium for the growth of these bacteria and, further, furnish a base or alkali to combine with the nitric acid produced by them. The nitrate of lime so formed, is, no doubt, the immediate source of nitrogen supply of our field crops.

COMPARATIVE VALUES OF LIME COMPOUNDS

All forms of lime used in agriculture are not of equal value, especially for the correction of acidity. In acid-correcting power and in furnishing available lime, and considering the various forms on a basis of equal purity, 56 pounds of quicklime is the equivalent of 74 pounds of freshly slaked lime and of 100 pounds of carbonate of lime, whether it be as marl or ground limestone. Air-slaked lime, for reasons already noted, may be partly hydrate and partly carbonate; its value will, therefore, be intermediate betwen that of freshly-slaked lime and the carbonate; that is, 56 pounds of quicklime will be equal to a weight of air-slaked lime between 74 and 100 pounds. Presenting these facts in tabular form we have:—

2,000 lb. quicklime=3,571 lb. of ground limestone or marl.
2,000 lb. quicklime=2,643 lb. of freshly-slaked lime.

If quicklime were worth $7 per ton, ground limestone, equally free from impurities, would be worth $4.10 per ton, and freshly-slaked lime, $5.50 per ton. While the above comparison, as to equivalent weights and values, may serve in a general way, an analysis is necessary when the exact lime value of any particular sample or samples is desired.

THE APPLICATION OF LIME COMPOUNDS

Quicklime.—In order to facilitate uniform distribution over the soil, quicklime should be slaked. Place the lime in small heaps of about a bushel each at regular distances on the field to be treated. Pour a little water, about one-third the weight of the lime, so that the slaking may be gradual and a fine powder result, on each; cover the heap with an inch or two of moist soil and allow to remain for two or three weeks, when the lime will be thoroughly slaked and fall into a fine powder. Mix the slaked lime with a little soil and spread with a shovel, choosing preferably a damp day for the work.

Forty heaps of about 50 pounds or twenty-five heaps of 80 pounds each is an application of approximately one ton per acre.

Slaked Lime.—This is in the form of a powder and may be most conveniently, pleasantly and uniformly spread by employing a lime spreader or fertilizer drill. It can, of course, be spread from a wagon box, but the operation is more or less disagreeable. If this method is adopted, the mixing of the slaked lime with a little fine soil is said to make the handling less unpleasant.

For these more caustic forms—quicklime and slaked lime—autumn is probably the best season for application, spreading on the ploughed land and immediately harrowing it in. The aim should be to incorporate the lime with the first three or four inches of the soil. The tendency for all lime compounds is to sink, to be washed down by the rain and, therefore, they should never be ploughed under. It is better to make light applications frequently, say, once in a rotation if necessary, than large applications at longer intervals. It is well to err on the side of too little than too much, especially if the organic content of the soil cannot be constantly enriched.

Ground Limestone, Marl.—The application of ground limestone and marl offers no special difficulty or unpleasantness; a spreader may be used or the material distributed by a shovel from a wagon. They may be applied at any season of the year and are specially suited for light loams and soils generally that are poor in organic matter. As with lime they should be harrowed in, not ploughed under, or in the case of meadows or pastures, merely spread on the surface.*

The application may be from two to four tons per acre, according to the character and the acidity of the soil and the degree of fineness of the material. Unlike quick and slaked lime, excess of ground limestone can do little or no harm and the same holds true of marl.

GYPSUM

Gypsum, commonly known in the ground form as land plaster, is a naturally-occurring sulphate of lime. Although supplying lime it is of no value for the correction of acidity (sourness) of soils, for which purpose lime or ground limestone must be employed. The furnishing of lime, however, does not constitute its main manurial value. It apparently has the property of acting on the insoluble potassic compounds of the soil, setting free for plant use a part of

* A more extended account of lime products and their uses in agriculture will be found in Bulletin No. 80 "Lime in Agriculture."

their potash. It has been found specially beneficial as a top dressing for clover, a crop that particularly responds to potash. The application of land plaster is usually from 500 to 1,000 pounds per acre, which may be broadcast on the prepared land and harrowed in.

Large deposits of gypsum occur in New Brunswick, Nova Scotia and Ontario, and as it is readily quarried and is comparatively soft material, land plaster may be purchased cheaply—in many districts at a lower price than ground limestone.

Users of superphosphate (acid phosphate) will have no necessity to apply land plaster since this phosphatic fertilizer contains sulphate of lime as a necessary constituent.

PEAT AND MUCK

Origin and Nature.—The deposits of peat and muck that are to be found more or less in all parts of Canada have been formed by the gradual accumulation of partially decomposed vegetable matter—the remains of successive generations of plants chiefly aquatic—in swamps and bogs, the sites of former lakes and ponds. These have been filled up by the gradual encroachment of vegetation from their shores. This semi-decayed vegetable matter contains valuable plant food. The peat or muck of these deposits have been and are being used to quite a considerable extent in farming practices as sources of organic matter (humus) and nitrogen and have been found valuable as a dressing for both clay loams and sandy loams deficient in these valuable constituents. Many peats and mucks serve admirably in the air-dried condition as absorbent litter. Muck areas also in many cases may be reclaimed and made fairly productive soils.

Definitions of Peat and Muck.—Peat may be briefly defined as semi-decayed vegetable matter, usually showing the structure of the plants from which it is formed. It is often more or less fibrous or woody, sometimes moss-like; and varies in colour from a light to dark brown when air-dried. As a rule it contains only small amounts of mineral matter (sand, silt and clay).

Muck is essentially vegetable organic matter in which decomposition or decay has reached a more advanced stage than in peat. It may or may not contain more or less clay and sand. As a rule the root fibres and plant tissues are well broken down, the original structure largely destroyed, and the bulk of the muck is of a black or dark brown oozy consistency when wet. Certain mucks can be readily reduced to a powder when dry, others cake on drying into more or less hard and refractory masses.

Composition of Peat and Muck.—Peat and muck are composed essentially of organic matter mixed with varying amounts of mineral matter—clay, sand, etc. In peats proper the percentage of clay, sand or other rock matter is usually very small, frequently less than 2 per cent in the air-dried material but may in many cases and more especially in true mucks reach 50·0 per cent or over. The vegetable matter of mucks and peats contains a notable percentage of nitrogen, usually between 1·0 to 2·0 per cent in the air-dried material. Mucks, as a rule, contain a higher percentage of nitrogen than peats. When freshly dug, peat and muck contain approximately 70 to 80 per cent of water, which, as a rule, is reduced on air-drying to about 20 per cent.

Treatment of Peat and Muck for Use as a Soil Amendment.—The agricultural value of any particular sample of peat or muck is dependant upon the percentages of nitrogen and organic matter which it contains and its state of decomposition. Since the organic matter occurs in many stages of decay it follows that the fertilizing effect of different samples is very variable, but in none of them can we suppose the nitrogen to be in such combinations as to be

immediately available to crops. Mucks, by reason of their being much further decomposed and broken down than peats are to be preferred for soil dressings. Peat in its crude and raw condition cannot be expected to at once benefit a soil save in such cases as it might improve its mechanical condition.

These deposits are often distinctly acid or sour (due to the method of formation) and consequently it is frequently necessary to render them alkaline by composting with lime or wood ashes, before the process of nitrification (whereby the nitrogen is made available for plants) can be induced. This sweetening process may also be accomplished to a large extent by digging and allowing the material to lie for several months exposed to the air.

Speaking generally, the application of peat and muck in the crude and raw condition is not to be advised, for, as already pointed out, their plant food does not exist in immediately available forms. Fermentation is necessary to set it free. This may be accomplished by the following treatments:

The material after digging (preferably in the fall) should be piled and allowed to remain exposed to the action of the air and frost throughout the winter, if possible. The air-dried and roughly powdered peat or muck may then be used as an absorbent in and about farm buildings or it may be composted with manure.

Used as an absorbent the air-dried material makes an excellent medium for soaking up liquid manure—a fertilizing material rich in nitrogen and potash—likely to go to waste. It may be placed behind the stock in the gutter of the stables or anywhere in which liquid is apt to accumulate, absorbing from 2 to 6 times its weight of liquid. Its use keeps the buildings sweet and clean and facilitates the cleaning of the stables. The resulting manure, now largely increased in bulk and value may be taken at once to the fields or may be allowed to stand in a heap for some little time. Fermentation will proceed quite rapidly and the nitrogen contained in the organic matter of the peat and muck will be largely rendered available to plant use. Owing to its coarser and more fibrous nature peat often makes a better absorbent than muck.

Peat and muck may be composted with barnyard manure and their fertilizing value thereby greatly enhanced. Sufficient manure to set up active fermentation in the peat and muck should be used to bring about the decomposition of the latter. One method of constructing a compost heap is to spread the peat or muck on the ground to a depth of 1 or 1½ feet making the width of the heap about 8 to 10 feet and length in accordance with the size desired. Cover this with a layer of manure from 8 to 12 inches thick, and continue with alternate layers of peat or muck and manure until the heap is 4 to 5 feet high. The heap should be *kept moist* but not saturated and after standing for a few weeks should be forked over. This operation may be repeated about once a month for three or four months moistening if necessary with liquid manure or water, when the compost should be in excellent condition for application to the soil.

Peat and muck treated as above outlined make valuable dressings for both clay loams and sandy loams, and furnish an increased bulk of good manure which is greatly to be desired on farms of low fertility and on which the supply of manure is usually limited. Lime and wood ashes may be used in composting the peat or muck to destroy acidity; but these materials should not be used with manures in the heap.